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ABSTRACT

This self-study course is designed to familiarize Marine enlisted personnel with the principles of the refrigeration process. The course contains five study units. Each study unit begins with a general objective, which is a statement of what the student should learn from the unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Text is furnished, illustrated as needed, for each work unit. At the end of the work units are study questions, with answers listed at the end of the study unit. A review lesson completes the course. The five units of the course cover the following subjects: fundamentals of refrigeration, refrigerants and lubricants, refrigeration systems and components, refrigeration controls, and air conditioning. (KC)

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UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE
ARLINGTON, VA 22222-0001

11.61
30 June 1986

1. ORIGIN

MCI course 11.61, Fundamentals of Refrigeration, has been prepared by the Marine Corps Institute.

2. APPLICABILITY

This course is for instructional purposes only.

H. L. Hughes

H. L. HUGHES
Deputy Director

ACKNOWLEDGEMENT

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INFORMATION
FOR
MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. AMERICAN COUNCIL ON EDUCATION (ACE) ACCREDITATION

Many of MCI's MOS courses have been evaluated by ACE and determined to have equivalency credit in either the Vocational Certificate (VC) category or the Baccalaureate/Associate Degree (BA) level.

If you are enrolled in a college or vocational program or plan to enroll and have completed one or more MCI courses, you may be able to receive college or vocational credit for them. All that you need to do is to petition your school to see if they will award you credit for the courses that apply to your program area. You will need your completion certificate, and the Evaluation of Educational Experiences in the Armed Services.

9. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action will adversely affect the unit's completion rate.

10. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

Personnel/Administration/Corrections/Logistics Embarkation/Maintenance Management	288-3259
Communications/Electronics/Aviation/NBC/Intelligence	288-3604
Infantry	288-3611
Engineer/Motor Transport/Utilities	288-2275
Supply/Food Services/Fiscal	288-2295
Tanks/Artillery/Infantry Weapons Repair Assault Amphibian Vehicles	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175

For commercial phone lines, use area code 202 and prefix 433 instead of 288.

FUNDAMENTALS OF REFRIGERATION

Course Introduction

FUNDAMENTALS OF REFRIGERATION is designed to familiarize the student with the principles of the refrigeration process.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Study Hours	Subject Matter
1	3	Fundamentals of Refrigeration
2	4	Refrigerants and Lubricants
3	5	Refrigeration Systems and Components
4	4	Refrigeration Controls
5	4	Air Conditioning
	3	REVIEW LESSON
	3	FINAL EXAMINATION
	26	

- -

RESERVE RETIREMENT CREDITS:	9
EXAMINATION:	Supervised final examination without text or notes with a time limit of 3 hours.
MATERIALS:	MCI 11.61, Fundamentals of Refrigeration. Review lesson and answer sheet.
RETURN OF MATERIALS:	Students who successfully complete this course are permitted to keep the course materials. Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

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SOURCE MATERIALS

TM 5-745	Heating, Ventilating Air-conditioning and Sheet Metal Works, Oct 1968
NAVEDTRA 10660	Utilitiesman 3 & 2, Vol 1, 1983
NAVEDTRA 10661	Utilitiesman 3 & 2, Vol 2, 1983
NAVEDTRA 13004	Refrigeration and Air-Conditioning, 1980

- -

HOW TO TAKE THIS COURSE

This course contains 5 study units. Each study unit begins with a general objective which is a statement of what you should learn from the study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit are study questions which you should be able to answer without referring to the text of the work unit. After answering the questions, check your answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit until you understand the correct responses. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

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MARINE CORPS INSTITUTE

STUDY GUIDE

Welcome to the Marine Corps Institute correspondence training program. By enrolling in this course, you have shown a desire to improve the skills you need for effective job performance, and MCI has provided materials to help you achieve your goal. Now all you need is to develop your own method for using these materials to best advantage.

The following guidelines present a four-part approach to completing your MCI course successfully:

1. Make a "reconnaissance" of your materials;
2. Plan your study time and choose a good study environment;
3. Study thoroughly and systematically;
4. Prepare for the final exam.

I. MAKE A "RECONNAISSANCE" OF YOUR MATERIALS

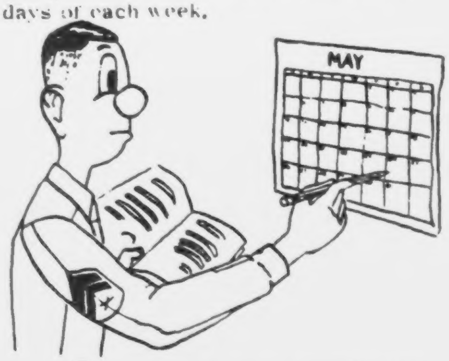
Begin with a look at the course introduction page. Read the COURSE INTRODUCTION to get the "big picture" of the course. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see Information for MCI Students to find out how to get them. If you have everything that is listed, you are ready to "reconnoiter" your MCI course.

Read through the table(s) of contents of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit questions to get an idea of the types that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, get down to specifics!

II. PLAN YOUR STUDY TIME AND CHOOSE A GOOD STUDY ENVIRONMENT

From looking over the course materials, you should have some idea of how much study you will need to complete this course. But "some idea" is not enough. You need to work up a personal study plan; the following steps should give you some help.

Ⓐ Get a calendar and mark those days of the week when you have time free for study. Two study periods per week, each lasting 1 to 3 hours, are suggested for completing the minimum two study units required each month by MCI. Of course, work and other schedules are not the same for everyone. The important thing is that you schedule a regular time for study on the same days of each week.



Ⓑ Read the course introduction page again. The section marked ORDER OF STUDIES tells you the number of study units in the course and the approximate number of study hours you will need to complete each study unit. Plug these study hours into your schedule. For example, if you set aside two 2-hour study periods each week and the ORDER OF STUDIES estimates 2 study hours for your first study unit, you could easily schedule and complete the first study unit in one study period. On your calendar you would mark "Study Unit 1" on the

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appropriate day. Suppose that the second study unit of your course requires 3 study hours. In that case, you would divide the study unit in half and work on each half during a separate study period. You would mark your calendar accordingly. Indicate on your calendar exactly when you plan to work on each study unit for the entire course. Do not forget to schedule one or two study periods to prepare for the final exam.

Ⓒ Stick to your schedule.

Besides planning your study time, you should also choose a study environment that is right for you. Most people need a quiet place for study, like a library or a reading lounge; other people study better where there is background music; still others prefer to study out-of-doors. You must choose your study environment carefully so that it fits your individual needs.

III. STUDY THOROUGHLY AND SYSTEMATICALLY

Armed with a workable schedule and situated in a good study environment you are now ready to attack your course study unit by study unit. To begin, turn to the first page of study unit 1. On this page you will find the study unit objective, a statement of what you should be able to do after completing the study unit.

DO NOT begin by reading the work unit questions and flipping through the text for answers. If you do so, you will prepare to fail, not pass, the final exam. Instead, proceed as follows:

Ⓐ Read the objective for the first work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

Ⓑ Without referring to the text, answer the questions at the end of the work unit.

Ⓒ Check your answers against the correct ones listed at the end of the study unit.

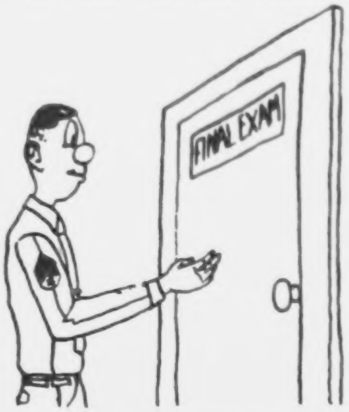
Ⓓ If you miss any of the questions, restudy the work unit until you understand the correct response.

Ⓔ Go on to the next work unit and repeat steps Ⓐ through Ⓓ until you have completed all the work units in the study unit.

Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your section OIC or NCOIC for help. If he cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course.

When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet listing course references for any questions that you miss.

IV. PREPARE FOR THE FINAL EXAM



How do you prepare for the final exam? Follow these four steps:

Ⓐ Review each study unit objective as a summary of what was taught in the course.

Ⓑ Reread all portions of the text that you found particularly difficult.

Ⓒ Review all the work unit questions, paying special attention to those you missed the first time around.

Ⓓ Study the course review lesson, paying particular attention to the questions you missed.

If you follow these simple steps, you should do well on the final. GOOD LUCK!

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STUDY UNIT 1

FUNDAMENTALS OF REFRIGERATION

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE LAWS OF REFRIGERATION, HEAT, PRESSURE, AND THE THREE PHYSICAL STATES OF A SUBSTANCE.

Long before modern day refrigeration, there was a need for preserving food. Most foods when kept at room temperature, spoil very rapidly due to the rapid growth of bacteria. Refrigeration temperatures of about 40° Fahrenheit (approximately 4° Celsius) slow the growth of bacteria, therefore foods can be kept for longer periods of time. Besides preserving foods, refrigeration can be used for air conditioning, for cooling beverages, and for controlling the humidity of the air.

We have learned through our western history that refrigeration was first used by the ancient Egyptians, Greeks, and Romans, who cooled water in vessels of porous material which extracted some of the heat by evaporation. History also reveals that the snows of Lebanon were brought by slaves to cool the wine for Caesar's feasts. Foods were kept fresh by placing them in vessels which were immersed in cool running streams. As time passed, farmers used spring houses made of stone and erected over flowing streams to obtain water for their household use. The temperature of the spring water was much lower than that of the outside air. This temperature difference was the basis for our great grandfather's version of refrigeration. Still another method of preserving food, extensively used throughout the New England and Middle Atlantic States, was that of chopping and sawing ice from lakes and ponds in the winter and storing it in cellars insulated with sawdust and straw which were then used in the hot summer months. During colonial times and well into the nineteenth century, ice was an important commodity used to trade with countries that did not produce natural ice. We can say that this method of trade was the beginning of commercial refrigeration.

The first time that ice was made artificially was in 1820; however, artificially produced ice did not become practical until 1834. It was at this time that an American engineer named Jacob Perkins invented an apparatus which was to become the forerunner of the modern compression systems. Refrigeration progress remained at a standstill until around 1890, at which time there was a shortage of natural ice because of an unusual warm winter. From then on artificial ice making really began developing into the great industry that is known today.

The refrigeration field is expanding swiftly. As a result a need for refrigeration specialists increases.

As a Marine Refrigeration Technician (MOS 1161), you will be responsible for the installation, operation, and maintenance of the refrigeration and air conditioning equipment that is used in the Marine Corps.

This course will deal with the basic principles of refrigeration. Specific items of refrigeration equipment will be covered in a separate course of study. Consult the current edition of the Marine Corps Institute Catalog for other courses pertaining to refrigeration equipment.

Work Unit 1-1. FUNDAMENTALS

STATE THE FIVE THERMAL LAWS OF REFRIGERATION.

LIST THE THREE PHYSICAL STATES OF A SUBSTANCE.

In the study of refrigeration, it is important at first to master some of the basic chemical, physical, and mechanical principles, since it must be noted from the start that all refrigeration systems depend on five thermal laws. You, as a refrigeration technician, should have a working knowledge of these five laws, as they will assist you in understanding what is taking place within the refrigeration system. The following is a list of these laws:

Fluids absorb heat while changing from a liquid state to a vapor state, and they will give up heat in the process of changing from vapor to liquid.

The temperature at which a change of state occurs is constant during the change provided the pressure remains constant.

Heat flows only from a body which is at a higher temperature to a body which is at a lower temperature (hot to cold).

Metallic parts of the evaporator and condensing units are metals which have a high heat conductivity.

Heat energy and other forms of energy are interchangeable.

All refrigerating systems depends on the five thermal laws listed above in one way or another. During your progress through this course, you will see how each of these laws works at different points throughout the cycle or system. Therefore, for your benefit, it is suggested that you spend a few minutes rereading these thermal laws so that you have them well in mind before proceeding with this study unit.

To start the ground work for this course on refrigeration theory, you will be given some general definitions. The following are just a few of the definitions that you should become familiar with since they are used quite often throughout this course.

- HEAT - "What is heat?" Heat is defined as a form of energy transferred by virtue of a difference in temperature. Heat exists everywhere in greater or lesser degrees. As a form of energy, it can be neither created nor destroyed, although other forms of energy may be converted into heat and vice versa. Heat energy travels in only one direction: from a warmer to a cooler object or space. It is invisible, but it is recognized by the effects it has on the surrounding air, the human body, and other matter.

- COLD - This is a term referring to the lack of heat in an object or space. Some definitions describe it as the absence of heat, but there is no object or space known in the world today from which heat is totally absent. A total absence of heat is referred to as "Absolute Zero." As of yet, no process has been devised that has been capable of achieving the state in which all heat has been removed from a space or object. Theoretically, this zero point would be 459.69 degrees below zero on the Fahrenheit scale, or 273.16 degrees below zero on the Celsius thermometer scale.

- REFRIGERATION - This occurs when unwanted heat from a selected space or object is removed and transferred to another space or object. Removal of heat lowers the temperature and may be accomplished in numerous ways (i.e., ice, snow, chilled water, or mechanical refrigeration).

- MECHANICAL REFRIGERATION - This is accomplished by utilizing mechanical components arranged in a refrigeration system for the purpose of transferring heat.

- REFRIGERANTS - These are chemical compounds that are alternately compressed and condensed into a liquid and then permitted to expand into a vapor or gas as they are pumped through the mechanical refrigeration system or cycle.

Before you proceed more deeply into the study of refrigeration, it is imperative that you have an understanding of matter.

All known matter exists in one of three states. It may exist as a SOLID, a LIQUID, or a GAS (vapor). We are all familiar with these three physical states because under ordinary conditions some substances are solid, others are liquid and still others are gases. We also know, in a general way, that many substances can exist in all of the three physical states, depending upon the conditions. For example: water ordinarily exists as a liquid; however, if the temperature is lowered sufficiently, water becomes a solid; if the temperature of water is raised, it becomes a gas (vapor).

In a solid, the motion of the molecules is restricted to such a degree that the substance will maintain its shape. For example, a cube of steel or wood or any other solid material will retain its cubical shape indefinitely. Put a block of wood on a table top, and the block of wood will remain a block of wood.

In a liquid, the molecules are much freer to move and as a result, a liquid will not retain its shape. Pour a little water on a table and the water will spread out in all directions. Since a liquid is fairly heavy, gravity will prevent it from rising and as a result, the liquid will simply spread out until it forms a thin layer on any surface on which it is poured. If it is poured into a container, it will conform to the shape of the container, except that the top surface will be level because the force is uniform over the entire surface of the liquid.

In a gas, the molecules are spread so far apart and are so free to move that the force of gravity has very little effect on them. A gas will, therefore, expand in all directions. If you put a small quantity of a gas into a container, the gas will quickly fill the container uniformly. There will be no level above which there is no gas, as there is in the case of the liquid.

There are many substances which can exist in all three states depending upon their temperature and the pressure exerted on them. You will be introduced to some of the substances as you progress through this course.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. According to the thermal laws used in refrigeration, heat flows in which direction?

   ____

2. The temperature at which a change of state occurs is constant during the change provided ____

3. Other forms of energy in addition to ______________ energy are interchangeable.

4. What must the metallic parts of the evaporating and condensing unit possess according to the thermal laws of refrigeration?

   ____

5. In accordance with the thermal laws, at what point do fluids absorb heat?

   ____

6. List the three physical states of matter.

   a. ______________________

   b. ______________________

   c. ______________________

Work Unit 1-2. HEAT BEHAVIOR

NAME THE TWO MEASUREMENTS OF HEAT.

CONVERT TEMPERATURES FROM THE FAHRENHEIT SCALE TO THE CELSIUS SCALE AND VICE VERSA.

DEFINE THE BRITISH THERMAL UNIT.

CALCULATE THE QUANTITY OF HEAT NECESSARY TO PRODUCE A GIVEN TEMPERATURE CHANGE IN WATER.

IDENTIFY THE DIFFERENCES BETWEEN SENSIBLE AND LATENT HEAT.

NAME THE THREE TYPES OF HEAT TRANSFER.

STATE THE TYPE OF HEAT TRANSFER USED MOST OFTEN IN REFRIGERATION.

Perhaps you thought you would start out your study of refrigeration by studying COLD since this is a course in refrigeration. However, as odd as it may seem, you must always think in terms of HEAT to understand how a refrigerator, air conditioner, or any other refrigeration system works, and before you realize it, you will be thinking in terms of heat with the "pros."

Heat, as was stated earlier, is a form of energy, and it has the ability to do "work." Electricity is another form of energy which has the ability to do work. Like other forms of energy, heat energy cannot be measured directly like you measure gallons of water or pounds of steel. You can, however, measure the effect heat produces on a substance. Heat, when applied to most solids, makes them longer, wider, and/or taller. You know, for instance, that a section of a concrete pavement will expand when it absorbs heat in the summertime.

Practically all solids and liquids will expand when heat is applied; but, when heat is taken away from a substance, that substance will contract. You will recall that heat is a form of energy which is not measureable in itself, but the heat intensity or temperature of a substance can be measured on a temperature scale.

Temperature scales were formulated through the use of glass tubes with similar diameters and a reservoir for a liquid, such as mercury, that will expand and rise in the tube when heated. There are two types of scales commonly used in refrigeration and they are:

- FAHRENHEIT SCALE - This scale figure 1-1, is based on the relative positions of the mercury in the thermometer when water is at the freezing point and when water is boiling. In order to use this instrument to measure temperature in between these two points, the distance was divided into 180 equal increments which were called degrees. The point where water will either freeze or ice will melt, under normal atmospheric conditions, was labeled as 32 degrees. Whereas the location, on the scale (thermometer) where water would boil was indicated as 212 degrees.

- CELSIUS SCALE - This scale figure 1-1, formally referred to as centigrade, was based on the decision to divide the area between the freezing and boiling points of water into equal increments. 0 degrees indicates the freezing point and 100 degrees indicates the point at which water will boil.

You might wonder why the freezing point of water and the boiling point of water were chosen as standards for both thermometers. These were chosen simply because water has a very constant freezing and boiling temperature, moreover, because water is a very common substance.

There are two additional scales that are sometimes used in the refrigeration field. The RANKIN (R) SCALE, which uses the same divisions as the Fahrenheit scale, but sets the zero of the scale at the temperature where molecular action of all substances ceases. This is the point where no more heat can exist in a body and the temperature cannot be lowered any further. This point is referred to as "Absolute Zero." This temperature corresponds to -460 degrees Fahrenheit; therefore, water boils at 672 degrees Rankin (212 degrees + 460 degrees), assuming a standard atmospheric pressure is present.

The other scale is the KELVIN (K) SCALE, which uses the same division as the Celsius (formally centigrade) scale. Because of the larger division, absolute zero is 273 degrees below the standard setting. Therefore, water freezes at 273 degrees Kelvin and boils at 373 degrees Kelvin.

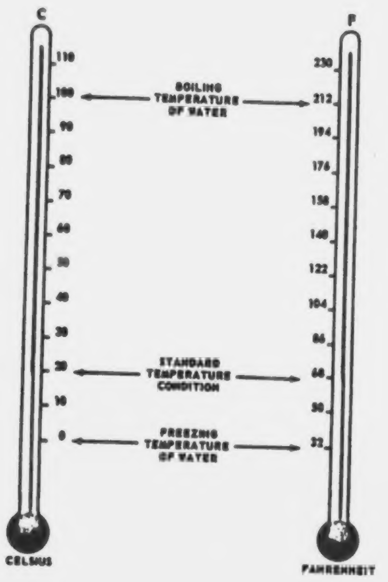
C
F
110
100
90
80
70
60
50
40
30
20
10
0
230
212
194
176
158
140
122
104
86
68
50
32
BOILING TEMPERATURE OF WATER
STANDARD TEMPERATURE CONDITION
FREEZING TEMPERATURE OF WATER
CELSIUS
FAHRENHEIT

Fig 1-1. A comparison between the Celsius and the Fahrenheit thermometer scales.

The last two scales are absolute scales and are used with very low temperature work such as cryogenics. Cryogenics refers to the use and creation of temperatures in the range of -157 degrees Celsius (C) down to -273 degrees Celsius, or -251 degrees Fahrenheit (F) down to -460 degrees Fahrenheit. You need to know only that the Kelvin and Rankine scales exist and are used in refrigeration. Refer to figure 1-2 for a comparison of the four temperature scales used in refrigeration work.

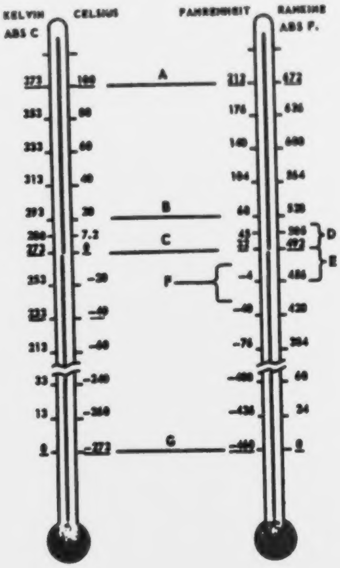
KELVIN
ABS C
CELSIUS
FAHRENHEIT
RANKINE
ABS F.
A
B
C
D
E
F
G
373
353
333
313
293
280
273
253
233
213
33
13
0
100
80
60
40
20
7.2
0
-20
-40
-60
-240
-260
-273
212
176
140
104
68
45
32
-4
-40
-76
-400
-436
-460
672
636
600
564
528
505
492
456
420
384
60
24
0

Fig 1-2. A comparison among Celsius, Fahrenheit,

Kelvin and Rankine thermometer scales.

A - Boiling temperature of water.

B - Standard conditions temperature.

C - Freezing temperature of water.

D - Temperature range for fresh foods.

E - Range of evaporator temperature for foods.

F - Temperature range for frozen food storage.

G - Absolute Zero.

As you work in the refrigeration field, from time to time it will become necessary for you to convert from Celsius to Fahrenheit or from Fahrenheit to Celsius. Most frequently, a conversion from one temperature scale to the other has been performed for you and shown on a conversion table. (Refer to table 1-1.)

Table 1-1. Temperature conversion.

°F	Temp. to be Converted	°C	°F	Temp. to be Converted	°C	°F	Temp. to be Converted	°C
-112.0	-80	-62.2	5.0	-15	-26.1	122.0	50.	10.0
-110.2	-79	-61.7	6.8	-14	-25.6	123.8	51	10.6
-108.4	-78	-61.1	8.6	-13	-25.0	125.6	52	11.1
-106.6	-77	-60.6	10.4	-12	-24.4	127.4	53	11.7
-104.8	-76	-60.0	12.2	-11	-23.9	129.2	54	12.2
-103.0	-75	-59.4	14.0	-10	-23.3	131.0	55	12.8
-101.2	-74	-58.9	15.8	-9	-22.8	132.8	56	13.3
-99.4	-73	-58.3	17.6	-8	-22.2	134.6	57	13.9
-97.6	-72	-57.8	19.4	-7	-21.7	136.4	58	14.4
-95.8	-71	-57.2	21.2	-6	-21.1	138.2	59	15.0
-94.0	-70	-56.7	23.0	-5	-20.6	140.0	60	15.6
-92.2	-69	-56.1	24.8	-4	-20.0	141.8	61	16.1
-90.4	-68	-55.6	26.6	-3	-19.4	143.6	62	16.7
-88.6	-67	-55.0	28.4	-2	-18.9	145.4	63	17.2
-86.8	-66	-54.4	30.2	-1	-18.3	147.2	64	17.8
-85.0	-65	-53.9	32.0	0	-17.8	149.0	65	18.3
-83.2	-64	-53.3	33.8	1	-17.2	150.8	66	18.9
-81.4	-63	-52.8	35.6	2	-16.7	152.6	67	19.4
-79.6	-62	-52.2	37.4	3	-16.1	154.4	68	20.0
-77.8	-61	-51.7	39.2	4	-15.6	156.2	69	20.6
-76.0	-60	-51.1	41.0	5	-15.0	158.0	70	21.1
-74.2	-59	-50.6	42.8	6	-14.4	159.8	71	21.7
-72.4	-58	-50.0	44.6	7	-13.9	161.8	72	22.2
-70.6	-57	-49.4	46.4	8	-13.3	163.4	73	22.8
-68.8	-56	-48.9	48.2	9	-12.8	165.2	74	23.3
-67.0	-55	-48.3	50.0	10	-12.2	167.0	75	23.9
-65.2	-54	-47.8	51.8	11	-11.7	168.8	76	24.4
-63.4	-53	-47.2	53.6	12	-11.1	170.6	77	25.0
-61.6	-52	-46.7	55.4	13	-10.6	172.4	78	25.6
-59.8	-51	-46.1	57.2	14	-10.0	174.2	79	26.1
-58.0	-50	-45.6	59.0	15	-9.4	176.0	80	26.7
-56.2	-49	-45.0	60.8	16	-8.9	177.8	81	27.2
-54.4	-48	-44.4	62.6	17	-8.3	179.6	82	27.8
-52.6	-47	-43.9	64.4	18	-7.8	181.4	83	28.3
-50.8	-46	-43.3	66.2	19	-7.2	183.2	84	28.9
-49.0	-45	-42.8	68.0	20	-6.7	185.0	85	29.4
-47.2	-44	-42.2	69.8	21	-6.1	186.8	86	30.0
-45.4	-43	-41.7	71.6	22	-5.6	188.6	87	30.6
-43.6	-42	-41.1	73.4	23	-5.0	190.4	88	31.1
-41.8	-41	-40.6	75.2	24	-4.4	192.2	89	31.7
-40.0	-40	-40.0	77.0	25	-3.9	194.0	90	32.2
-38.2	-39	-39.4	78.8	26	-3.3	195.8	91	32.8
-36.4	-38	-38.9	80.6	27	-2.8	197.6	92	33.3
-34.6	-37	-38.3	82.4	28	-2.2	199.4	93	33.9
-32.8	-36	-37.8	84.2	29	-1.7	201.2	94	34.4
-31.0	-35	-37.2	86.0	30	-1.1	203.0	95	35.0
-29.2	-34	-36.7	87.8	31	-0.6	204.8	96	35.6
-27.4	-33	-36.1	89.6	32	0.0	206.6	97	36.1
-25.6	-32	-35.6	91.4	33	0.6	208.4	98	36.7
-23.8	-31	-35.0	93.2	34	1.1	210.2	99	37.2
-22.0	-30	-34.4	95.0	35	1.7	212.0	100	37.8
-20.2	-29	-33.9	96.8	36	2.2	213.8	101	38.3
-18.4	-28	-33.3	98.6	37	2.8	215.6	102	38.9
-16.6	-27	-32.8	100.4	38	3.3	217.4	103	39.4
-14.8	-26	-32.2	102.2	39	3.9	219.2	104	40.0
-13.0	-25	-31.7	104.0	40	4.4	221.0	105	40.6
-11.2	-24	-31.1	105.8	41	5.0	222.8	106	41.1
-9.4	-23	-30.6	107.6	42	5.6	224.6	107	41.7
-7.6	-22	-30.0	109.4	43	6.1	226.4	108	42.2
-5.8	-21	-29.4	111.2	44	6.7	228.2	109	42.8
-4.0	-20	-28.9	113.0	45	7.2	230.0	110	43.3
-2.2	-19	-28.3	114.8	46	7.8	231.8	111	43.9
-0.4	-18	-27.8	116.6	47	8.3	233.6	112	44.4
1.4	-17	-27.2	118.4	48	8.9	235.4	113	45.0
3.2	-16	-26.7	120.2	49	9.4	237.2	114	45.6

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However, in the event that conversion tables are not available, formulas have been devised to facilitate the conversion. The formulas are based on the facts that Fahrenheit zero is located 32° below Celsius zero, and that the distance between the freezing point of water and the boiling point of water is 180° on the Fahrenheit scale and 100° on the Celsius scale. The conversion can be easily accomplished by a formula using either of the following equations:

- To convert Celsius to Fahrenheit:

$$^{o}F = 1.8\ (^{o}C + 32) \quad \text{or} \quad ^{o}F = 9/5\ ^{o}C + 32$$

- To convert Fahrenheit to Celsius:

$$^{o}C = \frac{^{o}F - 32}{1.8} \quad \text{or} \quad ^{o}C = \frac{5}{9}\ (^{o}F - 32)$$

Example: To convert a room temperature of 30°C to its equivalent on the Fahrenheit scale.

$$^{o}F = 1.8 \times 30 + 32 = 54 + 32 = 86^{o} \quad \text{or}$$

$$^{o}F = 9 \text{ divided by } 5 \times 30 + 32 = 54 + 32 = 86^{o}$$

Example: To convert a room temperature of 50°F to its equivalent on the Celsius scale.

$$^{o}C = (50 - 32) \text{ divided by } 1.8 = (18) \text{ divided by } 1.8 = 10^{o} \quad \text{or}$$

$$^{o}C = 5/9\ (50-32) = 5/9\ (18) = 90/9 = 10^{o}$$

You have just learned one way in which heat is measured: by the HEAT INTENSITY of a substance. Now, you will learn the other method by which heat is measured: by HEAT QUANTITY. Heat quantity is different from heat intensity, because it takes into consideration not only the temperature of the substance being measured but the weight of the substance. The BRITISH THERMAL UNIT (Btu) is the unit of heat quantity. It is defined as the amount of heat required to raise the temperature of 1 pound (lb) of water 1 degree Fahrenheit at sea level. Conversely, it is also the amount of heat that must be extracted to lower by 1 degree Fahrenheit the temperature of 1 lb of water. One Btu of heat quantity is a relatively small amount of heat. One kitchen match will produce about one Btu of heat. To compute Btu's, remember that one Btu is equal to a substance's weight in pounds multiplied by the temperature difference.

Example: If you were to calculate the amount of heat necessary to increase one quart of water (approx. 2.1 pounds) from 60°F to 75°F, your first step would be to determine the temperature difference which is 15° (75° minus 60°). Then, using the following formula you would compute the required Btu's:

HEAT QUANTITY = BTU

Btu = Weight (in pounds) x Temperature difference

$$\text{Btu} = 2.1 \text{ lbs} \times 15^{o}$$

$$\text{Btu} = 31.5$$

Example: If you were to calculate the amount of heat removed when 50 lbs of water is cooled from 90°F to 40°F the formula would be the same.

$$\text{Btu} = 50 \text{ lbs} \times 50^{o}$$

$$\text{Btu} = 2500$$

You have now covered the measurement of heat, heat intensity, and heat quantity. It should be noted at this time that the first law of thermodynamics, that section of science which deals with the mechanical action of heat, states that energy can neither be created nor destroyed; it can only be converted from one form to another.

So far you have considered the most obvious effects of heat energy on a substance. You have learned that heat energy, when added to most substances, causes them to become larger with an increase in heat intensity and heat quantity.

Now, consider another very important effect that heat energy has on a substance: When heat energy is added to a substance, the effect can be a CHANGE OF STATE. The term change of state is simply a technical term which means that there is a physical change in the materials. You are already familiar with these changes of state by using every day language:

- Melting a solid to a liquid - Heat is added
- Boiling a liquid to a vapor - Heat is added
- Condensing a vapor to a liquid - Heat is removed
- Freezing a liquid to a solid - Heat is removed

Note: HEAT ENERGY MUST BE ADDED TO A SUBSTANCE TO CHANGE ITS STATE FROM A SOLID TO A LIQUID OR FROM A LIQUID TO A VAPOR.

When water boils, it changes from water (liquid) to steam (vapor). This change is called a CHANGE OF STATE. If heat must be added to cause a substance to melt or boil, what similar statement could you make about changes of state from a vapor to a liquid or from a liquid to a solid? Let's see:

- Heat energy must be added to a substance to change its state from a solid to a liquid or from a liquid to a vapor.

  Example: Melting ice to water

  Boiling water to steam

- Heat energy must be taken away from a substance to change its state from a vapor to a liquid or from a liquid to a solid.

  Example: Condensing steam to water

  Freezing water to ice

Note: THE TEMPERATURE OF A SUBSTANCE DOES NOT CHANGE WHEN A CHANGE OF STATE IS TAKING PLACE.

If you combine this temperature rule with the heat rule you just learned, you can say that heat energy must be added to a substance to cause it to change from a solid to a liquid or from a liquid to a vapor, but the temperature does not change while the change of state is taking place. Or you could say: Heat energy must be taken away from a substance to cause it to change its state from a vapor to a liquid or from a liquid to a solid but the temperature does not change while the change of state is taking place.

Using water as an example, refer to figure 1-3 to see what happens to the temperature of water as heat is added at a uniform rate. Figure 1-4 shows what will happen if you were to remove heat at a uniform rate. You should also note that at the freezing point or at the boiling point temperature changes will not occur.

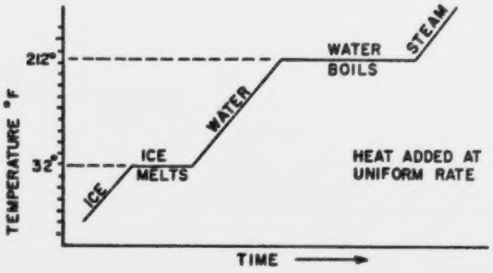


Fig 1-3. Adding heat at a uniform rate.

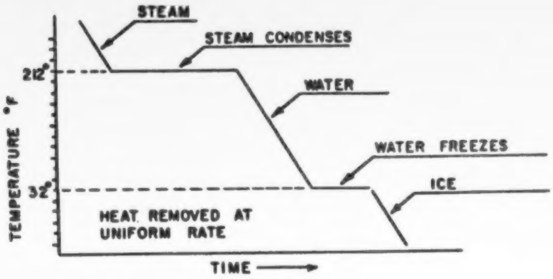


Fig 1-4. Removing heat at a uniform rate.

When heat is added to a substance and the temperature goes up, you know that a change of state has not taken place. The heat added can be "sensed." That is, you can SEE the temperature change on a thermometer, thus that heat is called SENSIBLE HEAT. When heat is added to a substance and the temperature stays the same, you know that a change of state has taken place. Heat added under this condition cannot be "sensed" with a thermometer, and since it cannot be sensed, it is called HIDDEN HEAT or LATENT HEAT. Remember, heat added to a substance that causes a rise in temperature is called SENSIBLE HEAT, and heat added to a substance that causes a change of state is called LATENT HEAT. The term sensible heat and latent heat refer to the effect heat has on a substance. Do not think that there are two kinds of heat energy. Heat is the same kind of energy whether it causes a temperature rise or a change of state. Figure 1-5 will show you sensible heat and latent heat.

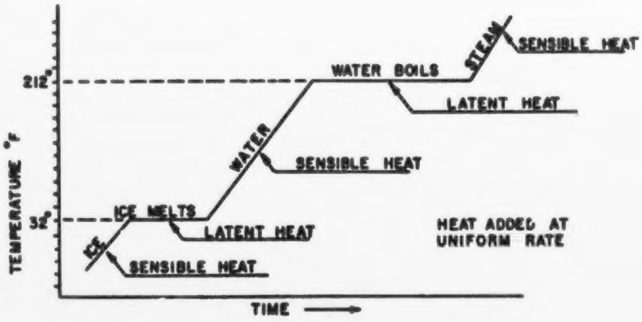


Fig 1-5. Sensible and latent heats.

Do you remember the definition of a Btu? One Btu is the amount of heat required to raise the temperature of one lb of water 1 degree Fahrenheit.

Just as a definite amount of heat is needed to raise the temperature of one lb of water one degree Fahrenheit, a definite amount of heat is needed to change the state of one lb of ice to water. To be exact, it takes 144Btu's to change one lb of ice at 32° F. to water at 32°F. Since a change of state occurs when the ice is melting, these 144 Btu's represent LATENT HEAT. Likewise, 144 Btu's must be removed from one lb of water at 32° F. to freeze the water to ice 32° F. Another word that could imply freezing is FUSION. You would say, then, that the LATENT HEAT OF FUSION of water is 144 Btu's per pound.

Remember, latent heat of fusion is the heat necessary to change 1 lb of a solid to a liquid without a change in temperature at standard atmospheric pressure. An equal amount of heat must be removed to change the liquid to a solid. For example, in changing 1 lb of water from a solid to a liquid (ice to water) or from a liquid to a solid (water to ice), you will add or extract 144 Btu's of heat. This quantity of heat is called latent heat of fusion. In figure 1-6, the pound of ice at 32° F begins to melt as shown by the horizontal line representing "ice melting." During the melting process the temperature of the ice and water do not change, but the heat content changes from 16 Btu's to 160 Btu's. The 144 Btu's difference is the latent heat of fusion.

Conversely, a definite amount of heat is necessary to change 1 lb of water at 212° F to steam at 212° F The heat necessary to change 1 lb of a liquid to a vapor without a change in temperature at standard atmospheric pressure is called LATENT HEAT OF VAPORIZATION. An equal amount of heat must be removed to change the vapor to a liquid. When this heat is absorbed from a vapor it is called LATENT HEAT OF CONDENSATION. Each material has its own value of latent heat of vaporization. A few examples are:

MATERIAL	LATENT HEAT OF VAPORIZATION
Water	970 Btu/lb at 212°F.
Refrigerant 12	68.5 Btu/lb at 5°F
Refrigerant 22	93.2 Btu/lb at 5°F

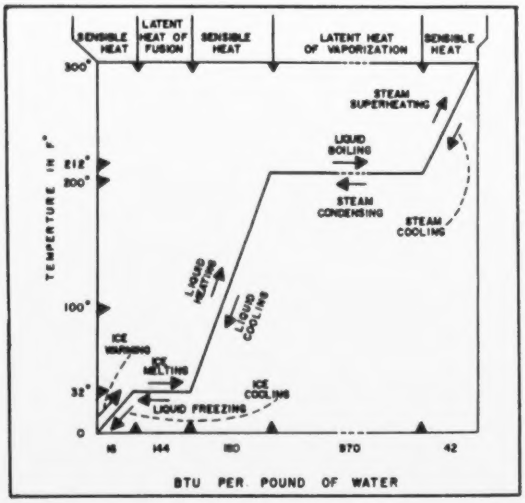


Fig 1-6. Effects of various types of heat.

In figure 1-6, when water attains a temperature, at standard atmospheric pressure, of 212°F, it begins to boil. The water temperature remains at 212°F. until 970 Btu's of heat have been added and the pound of water boils away as illustrated by one horizontal segment of the "liquid boiling." The 970 Btu's of heat needed to change the water to steam is called the LATENT HEAT OF VAPORIZATION.

Remember, any change of a substance such as from ice to water to steam is referred to as a change of state and a change of state is always accomplished by a GAIN or LOSS of latent heat.

Many substances can change their state from a solid to a liquid and from a liquid to a gas (vapor). Heat brings about these changes. Molecules of a substance are in constant motion or vibration. Heat is molecular energy which results from the motion of these molecules. The structure of the molecules dictates to a degree the molecular activity that occurs within a substance. For this reason, substances may exist in three physical states or forms. These physical states are SOLIDS, LIQUIDS, and GASES.

- SOLIDS: any physical substance which keeps its shape even when not contained. The molecules of the substance are strongly attracted to each other. Considerable force is necessary to separate them.
- LIQUIDS: any physical substance which freely takes the shape of its container, yet, its molecules are strongly attracted to one another.
- GASES: any physical substance which must be enclosed in a sealed container to prevent its escape into the atmosphere.

When heat is added to a substance, the rate of molecular motion increases, and the substance passes from solid to liquid to gas form. For example, in a cube of ice the molecular motion is slow, but as heat is added the molecular activity increases, thus changing the ice to a liquid. Further application of heat forces the molecules to separate further, thus increasing their motion to such an extent that water changes into steam or gas. Since heat is not a substance, it can best be considered in relation to its effect on substances or bodies.

We will now discuss tne methods used to move or transfer heat. Another thermodynamic law states that heat is always transferred in one direction - from a hot substance to a cold substance. This transfer is accomplished by one of three basic methods; they are CONDUCTION, CONVECTION, and RADIATION.

We will take a close look at each of the three methods separately. In practice, however, most heat transfer problems involve all three methods. You will find your knowledge of these basic methods a big help when servicing refrigeration equipment.

As stated earlier, heat flows from bodies of higher temperatures to bodies of lower temperatures (hot to cold) in the same manner that water flows down a hill; and like water, it can be pumped up again to a higher level so that it may repeat its flow downward. When two substances of different temperatures are brought in contact with each other, heat will immediately flow from the warmer substance to the colder substance. The greater the difference in temperature between the substances, the faster the heat flow. As the temperature of both substances tends to equalize, the flow of the heat will slow and stop completely when the temperatures are equalized. This characteristic of heat is utilized in refrigeration. The heat of the air and substances in a refrigeration space, or heat in food to be preserved, is transferred to the refrigerant, the colder substance. The three methods by which heat may be transferred from a warmer substance to a colder substance are, as was stated previously: CONDUCTION, CONVECTION, and RADIATION.

- CONDUCTION: This is the process of transferring heat from one part of a body to another part of the same body or between bodies that are touching, or in good contact with each other. Heat flowing along an iron bar, one end of which is held in a fire see figure 1-7, is a simple example of this process. Movement of heat continues until there is a temperature balance throughout the length of the bar. Conduction occurs when the conductor is in actual physical contact with the heat source and the point of delivery. Heat flows from the hot to the cold end of the bar by molecular activity.

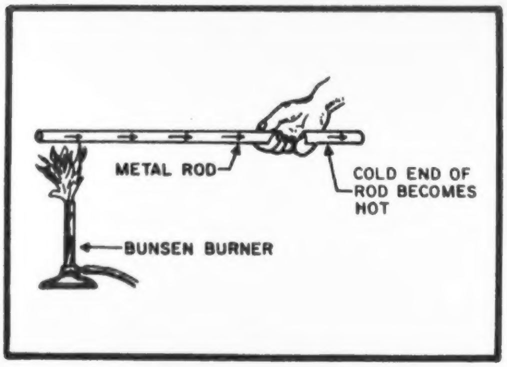


Fig 1-7. Heat transfer by conduction.

The speed of the heat transfer, by means of conduction, will vary with different materials, if the materials are of the same size. Also, the speed of heat transfer will vary according to the ability of the material to conduct heat flow. In the three physical states, solids are better conductors of heat than liquids and liquids are better than gases or vapor, depending on the materials being compared. Examples of good conductors are: copper, steel, aluminum, and silver. Examples of other solids which are NOT good conductors of heat and are referred to as insulators are: glass, wood, or other common building materials.

Copper and aluminum are excellent conductors of heat. These materials are used in the evaporators, condensers, and refrigerant pipes (tubes) connecting the various components of a refrigeration system.

The heat transfer that may be conducted through various materials is dependent upon:

- The thickness of the material.
- Its cross-sectional area.
- The temperature difference between the two sides of the material.
- The heat conductivity of the material.
- The time duration of the heat flow.

In a refrigeration system, it is desirable that rapid heat transfer occurs in both the evaporator and condenser; therefore, the materials that are used must have a high conductivity rating. As you will see later in this course, the evaporator is where heat is removed from a conditioned space or body and the condenser dissipates this heat to another medium or space.

- RADIATION: The second method of heat transfer is called radiation. This is the transfer of heat by heat rays. The sun's rays heat the earth by means of radiant heat waves, which travel in a straight path without heating the intervening matter or air. It should be understood that they heat ONLY the surface which they strike, see figure 1-8.

When you stand in front of a fire, you feel its warmth. Have you ever wondered how, or even why the heat of the fires reaches you? It does not do so by conduction because you are not in contact with the fire. It cannot do so by convection because, as you will see later, the heated air above the fire rises and the colder air from the sides move in to take its place. In other words, the convection currents flow from you to the fire, not from the fire to you. What is left? The answer is RADIATION.

All bodies containing heat, no matter how small an amount, radiate some of that heating in all directions in exactly the same way as a lighted lamp radiates light. As a matter of fact, these heat rays are of exactly the same nature as light rays except that their wave length is somewhat longer. Radio waves, heat rays, and light rays are all electromagnetic waves or radiation; the primary difference among them is only the length of their individual waves. When a radio wave strikes a good conductor of electricity, such as metal, the waves are absorbed and the energy they contain is converted into electrical energy, so that an electric current flows through the conductor. It is this current which is amplified and heard in radio and TV receivers.

When heat or light radiation strike any body which absorbs them, their energy is converted into SENSIBLE HEAT. If these radiation strike something which is transparent to them, they simply pass through with no effect. If you were to hold a sheet of glass in front of a fire, the glass would not warm up appreciably because both the light and the radiant heat pass through. However, if you were to hold a sheet of metal in front of the fire, the metal would rapidly heat up, because the heat and light rays are absorbed and converted into sensible heat. It should be pointed out that the heat rays, which have the longer wave length, contain most of the energy and, therefore, are mainly responsible for heating.

At low temperatures, there is only a small amount of radiation, and only minor temperature difference are noticed; therefore, radiation has very little effect in the actual process of refrigeration itself. However, results of radiation from heat rays can cause an increased refrigeration load. Heat transfer by radiation is a big factor when choosing air conditioning equipment.

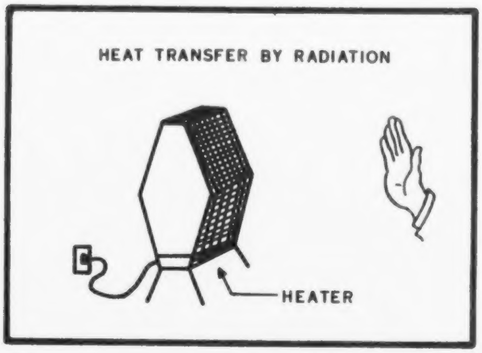


Fig 1-8. Heat transfer by radiation.

CONVECTION: The third and final means of heat transfer is by conveying or motion of the heated material itself and is limited to liquids or gas. This is called CONVECTION. A common example of this is the movement of heat laden air from a furnace into the rooms of a building where it releases its heat and then returns through the cold air duct to receive another supply of heat from the furnace, see figure 1-9.

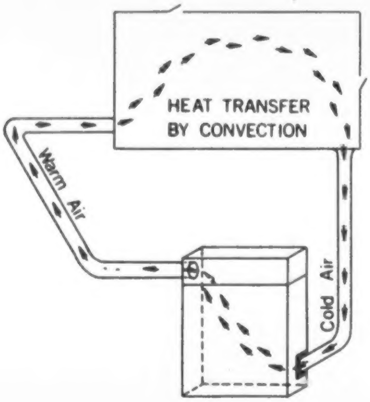


Fig 1-9. Heat transfer by convection.

Heat transfer by convection is such an important factor to refrigeration technicians that we must take a closer look at it.

Many refrigerators are constructed with "condenser" tubes at the rear of the cabinet, see figure 1-10. The condenser must give off heat to the room in order for the refrigerator to operate properly. Air close to the condenser gets warm by conduction and radiation, which were both covered earlier in this study unit. The warm air will rise, and the cooler air will take its place. The result is a continuous flow of air up the back of the refrigerator. This air movement transfers heat from the condenser to the room by convection.

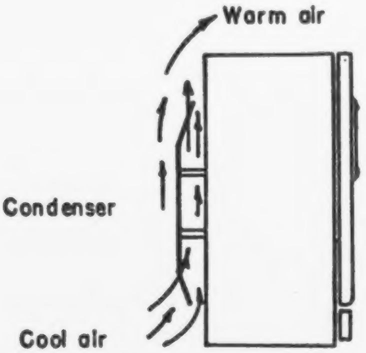


Fig 1-10. Refrigerator using convection.

So far we have described heat transfer by convection in which the air moves because warm air naturally rises and cool air takes its place. Can you describe the heat transfer process that takes place when a pan of water is heated on the surface unit of an electric range? Your answer should be something like this; "HEAT FROM THE SHOT SURFACE UNIT IS CONDUCTED THROUGH THE BOTTOM OF THE PAN TO THE LAYER OF WATER NEXT TO THE BOTTOM OF THE PAN. THIS HOTTER LAYER OF WATER RISES AND COOLER WATER TAKES ITS PLACE. THE RESULT IS A SLOW CIRCULATION OF THE WATER TRANSFERRING HEAT BY CONVECTION THROUGHOUT THE PAN." What would be the effect of stirring the water while it is being heated? . . . "STIRRING THE WATER HELPS THE TRANSFER OF HEAT THROUGHOUT THE PAN OF WATER." In other word, you FORCED the convection process to take place faster than it would have taken by itself. Heat is transferred by FORCED CONVECTION when some external force causes the air, water, or other fluids to move. If the movement of the air or water is not forced, then heat is transferred by NATURAL CONVECTION.

On the refrigerator in figure 1-10, heat was transferred from the condenser to the room by natural convection. The condenser on some refrigerators are located under the refrigerator cabinet. A fan pulls air from the room over the condenser and blows the warm air outside of the cabinet, see figure 1-11. In this case, heat is transferred by forced convection.

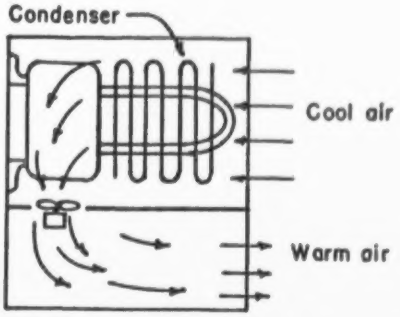


Fig 1-11. Refrigerator using forced convection.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Name the two ways in which heat is measured.

   a. ______________________

   b. ______________________

2. Name the two ways in which heat intensity is measured.

   a. ______________________

   b. ______________________

3. Define the British Thermal Unit (Btu).

   ____

   ____

4. Calculate the amount of heat, in Btu's, necessary to increase one gallon of water (8.4 pounds) from 65^{o} F to 85^{o} F.

   ____

5. Convert a room temperature of 20^{o} C to its equivalent on the Fahrenheit scale.

   ____

6. Convert a room temperature of 80° F to its equivalent on the Celsius scale.

____

7. What is the name given to the heat energy that causes a rise in temperature of a substance?

____

8 What is the name given to the heat energy that causes a change of state in substance?

____

9 Name the three types of heat transfer.

a. __________________________

b. __________________________

c. __________________________

10 What type of heat transfer is most important to the refrigeration field?

____

Work Unit 1-3. FLUIDS AND PRESSURE

DEFINE PRESSURE.

DESCRIBE ATMOSPHERIC PRESSURE.

GIVEN A GAGE PRESSURE READING CONVERT IT TO ABSOLUTE PRESSURE.

NAME THE MOST COMMON TYPE PRESSURE A GAGE USED IN REFRIGERATION.

NAME TWO VARIETIES OF PRESSURE GAGES.

STATE THREE LAWS THAT EFFECT PRESSURE-TEMPERATURE-VOLUME RELATIONSHIPS.

In the refrigeration cycle, you will work with an enclosed system where the effects of heat and pressure are highly related; therefore, as a next step you will examine the behavior of fluids and pressure.

The definition of pressure is the amount of force exerted on a substance per unit area. Substances always exert pressure on the surface supporting or containing them. A block of ice (a solid) exerts a pressure on its support. If the support is removed, the block would fall to another supporting level. A liquid always exerts a pressure on the sides and bottom of its container, such as a bottle. A gas always exerts a pressure on all the surfaces of its container, such as a balloon. Figure 1-12 shows examples of the effects produced by pressure on the three physical states of a substance.

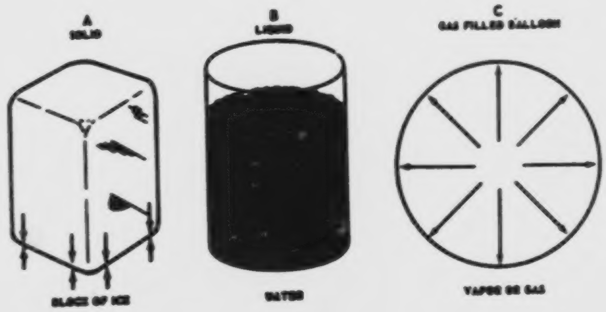


Fig 1-12. Effects of pressure.

In the refrigeration field, you will be dealing mostly with pressures that are exerted by gases or liquids.

Everything on or in the earth is subject to pressures of various sorts. The earth is surrounded by an ocean of air called the atmosphere. This air extends 50 or more miles upward from the surface of the earth. Even though air is very light, the miles of air above us must weigh a great deal. The weight and pressure that is exerted by this air is called "ATMOSPHERIC PRESSURE."

It has been determined that a column of air, with a cross-sectional area of one square inch and extending from the earth's surface at sea level to the limits of the atmosphere, would weigh approximately 14.7 pounds. This atmospheric pressure was first determined by an Italian physicist named Toricelli many years ago. He constructed a very simple barometer figure 1-13, using a long glass tube about 36 inches in length and closed at one end. He filled the tube with mercury and inverted it in a bowl of mercury, holding one of his fingers at the open end of the tube to prevent the mercury from spilling out while it was inverted. When he removed his fingers, he found that the mercury did not run out of the tube as he might have expected. Instead, the level dropped only slightly, as shown in figure 1-13. When he measured the height of the column of mercury, he found it to be 29.92 inches. He reasoned that the force which was holding the mercury up was the weight of the air pressing down on the exposed mercury in the bowl. It follows from this that the weight of the air pressing down on the mercury in the bowl was exactly equal to the weight of a column of mercury approximately 30 inches long. It was then easy enough to determine that a column of mercury, having a cross-sectional area of one square inch and a height of 30 inches, weighed 14.7 lbs. You know, therefore, that the air above you exerts a pressure 14.7 pounds per square inch (psi). This device is still used for precise measurements of air pressure since air pressure is seldom exactly 14.7 pounds per square inch, but varies slightly, depending upon temperature, altitude and water vapor content in the air. When this device is used to determine weather conditions it is called a BAROMETER. If it is used in the laboratory, in a modified form, for the precise measurements of low gas pressure it is called a MANOMETER. Both devices indicate pressure by the height of the mercury column. and they are directly calibrated to read in inches of mercury, rather than in pounds per square inch. It is a simple matter to convert inches of mercury into pounds per square inch if it becomes necessary.

A manometer is one type of device utilized in the refrigeration and air conditioning field for the measurement of pressure. This type of pressure gage utilizes a liquid usually mercury, water, or gage oil, as a indicator of the amount of pressure involved.

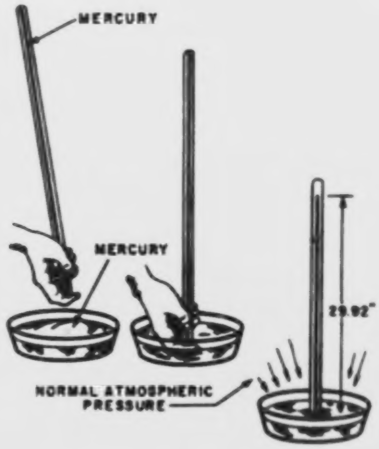


Fig 1-13. Simple barometer.

A space that is void, or lacking any pressure, is described as a PERFECT VACUUM. If the space has pressure less than atmospheric pressure, it is defined as a partial vacuum. It is customary to express this vacuum in INCHES OF MERCURY and not as negative pressure. In some instances, it is also referred to as a given amount of absolute pressure, expressed in POUNDS PER SQUARE INCH ABSOLUTE. This will be covered later in this work unit. When air is exhausted from a sealed container, pressure within the container is reduced below atmospheric pressure and a partial vacuum is formed. Any pressure below atmospheric pressure is indicated in inches on the vacuum gage. Every 2 inches of vacuum is equal to approximately 1 psig below atmospheric. From this it can be noted that 30 inches of vacuum equals 0 psia and at 14.7 psia pressure the gage pressure is 0 psig.

Gages are used to measure pressure. The pressure gages most commonly used by refrigeration technicians to determine what is going on within the refrigeration system are Bourdon tubes. Figure 1-14 is an internal view of the bourdon tube pressure gage. The essential element of this gage is the Bourdon tube itself. The oval metal tube is curved along its length and forms an almost complete circle. One end of the tube is closed, and the other end is connected to the equipment or component being tested.

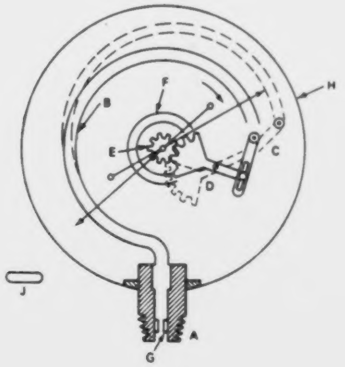


Fig 1-14. Internal construction of a pressure gage.

Note: The following is an explanation of the internal components of the Bourdon tube pressure gage: (The dotted line indicates how the pressure in the Bourdon tube causes it to straighten and operate the gage.)

A - Adapter fitting, usually an 1/8" pipe thread

B - Bourdon tube

C - Link

D - Gear sector

E - Pointer shaft gear

F - Calibrating spring

G - Restricter

H - Case

J - Cross-section of the Bourdon tube

Ordinary pressure gages are calibrated with zero representing atmospheric pressure (14.7 psi). In other words, if the gage is not connected to anything and is open to the air, it will read zero, even though it is actually reading pressure. In the case of the Bourdon tube, any additional pressure applied, when the gauge is connected to a component, will tend to straighten out the bourdon tube, thereby moving the needle and its mechanical linkage, thus, indicating the amount of pressure being applied.

There are two typical pressure gages used in refrigeration work. One is a PRESSURE GAGE which indicates the amount of pressure above that of the atmosphere see figure 1-15, and the other is a COMPOUND PRESSURE GAGE see figure 1-16, which has, as the name implies, a dual function: that of registering a pressure above atmospheric pressure and that of registering pressures that are below the atmospheric pressure.

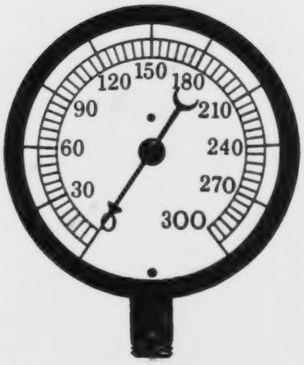


Fig 1-15. Single function gage.

Pressures below atmospheric pressure are customarily expressed in inches of mercury (Hg). This is shown on the compound gage, see figure 1-16, from 0 down to 30.

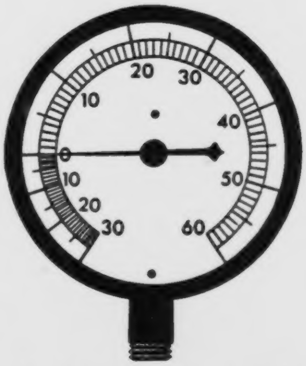


Fig 1-16. Compound gage.

In your work as a refrigeration technician, if it becomes necessary, to make a distinction or to be more exact, use the term "gage pressure" and "absolute pressure" if you are starting from absolute zero. To convert gage pressure to absolute pressure, simply add 14.7 psi.

Remember, absolute pressure is measured from absolute zero pressure rather than normal or atmospheric pressure. It is equal to the atmospheric pressure (14.7 psi) ADDED to the gage pressure. Gage pressure (psig) is used on most gage scales and is measured from above atmospheric pressure. It is equal to absolute pressure LESS 14.7 psi.

Figure 1-17 will show you a definite relationship among atmospheric, absolute, and gage pressure. For many problems atmospheric pressure does not need to be considered; therefore, the customary pressure gage is calibrated and graduated to read zero under normal atmospheric conditions. Yet, when gages are contained within an enclosure away from the atmosphere, such as in a refrigeration unit, it is necessary to take atmospheric pressure into consideration, and mathematical calculations must be in terms of the absolute pressure involved.

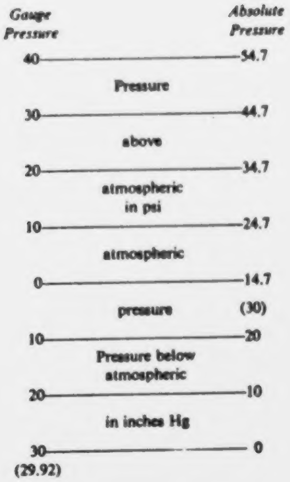

Gauge Pressure
Absolute Pressure
40
54.7
Pressure
30
44.7
above
20
34.7
atmospheric in psi
10
24.7
atmospheric
0
14.7
pressure
(30)
10
20
Pressure below atmospheric
20
10
in inches Hg
30
(29.92)
0

Fig 1-17. Relationship between absolute, atmospheric, and gage pressure.

In the study of refrigeration, it is important to understand some of the ways in which pressure effects liquids and gases, and some of the relationships between pressure, temperature, and volume in gases.

The pressure-temperature-volume relationships of gases are expressed by three laws:

- BOYLE'S LAW: It states that the volume of any gas varies inversely (opposite) with its pressure, provided the temperature remains constant. This means that the product of the pressure times the volume remains constant, or that if the pressure of a gas doubles, the new volume will be one half of the original volume. Or it may be considered that, if the volume is doubled, the absolute pressure will be reduced to one half of what it was originally. This law may be expressed as an equation in the following manner:

$$V_1 P_1 = V_2 P_2$$

In this equation V_1 is the original volume of the gas, P_1 is its original pressure, V_2 its new volume and P_2 its new pressure. It must be remembered that P_1 and P_2 have to be expressed in the ABSOLUTE PRESSURE terms for the equation to be used correctly. Figure 1-18 can be used to illustrate this:

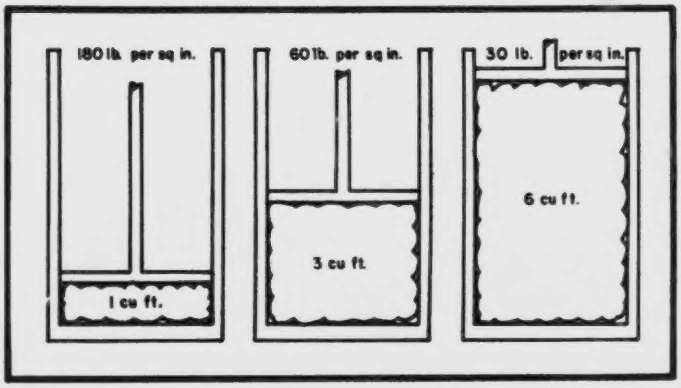

180 lb. per sq in.
1 cu ft.
60 lb. per sq in.
3 cu ft.
30 lb. per sq in.
6 cu ft.

Fig 1-18. Effects of pressure on volume.

If 3 ft^3 of a gas is placed in a cylinder, and a piston exerting 60 psig is inserted in the open end, and if the piston is pushed down into the cylinder and compresses the gas into 1 ft^3., the pressure exerted would have to be 180 psig; if the piston were withdrawn so that there were 6 ft^3 of gas, the pressure would be reduced to 30 psig.

Example: If the gage pressure on 2 ft^3 of gas is increased from 20 psig to 50 psig while the temperature of the vapor remains constant, what will be the new volume?

P_1 = 20 psig + 14.7 (atmospheric pressure) = 34.7 psia

P_2 = 50 psig + 14.7 (atmospheric pressure) = 64.7 psia

V_1 = 2 ft^3

V_2 = ?

using the formula $V_1 \times P_1 = V_2 \times P_2$, you would transpose the formula into the following:

V_2 = (P_1 x V_1) divided by P_2

V_2 = (34.7 x 2) divided by 64.7

V_2 = 1.072 ft^3

Example: If additional pressure is applied to a volume of 2 ft^3 of gas at 20 psig so that the volume is lessened to 1.072 ft^3, and the temperature of the gas remains constant, what is the new pressure in psig?

P_1 = 34.7 psia (20 psig + 14.7 atmospheric pressure)

V_1 = 2 ft^3

V_2 = 1.072 ft^3

P_2 = ?

using the formula $V_1 \times P_1 = V_2 \times P_2$, you would transpose the formula into the following:

P_2 = (P_1 x V_1) divided by V_2

You would insert all the given values as follows:

P_2 = (34.7 x 2) divided by 1.072; therefore P_2 will equal 64.7 psia

Now you would subtract atmospheric pressure from P_2 as follows:

P_2 = 64.7 - 14.7, therefore the answer would be 50 psig for P_2.

Again, it must be remembered that P_1 and P_2 have to be expressed in the ABSOLUTE PRESSURE TERMS for the equation to be used correctly.

- CHARLE'S LAW: It states that the volume of a gas is in direct proportion to its absolute temperature, providing the pressure is kept constant and the absolute pressure of a gas is in direct proportion to its absolute temperature, providing the volume is kept constant. The equations for this law are as follows:

V_1 divided by V_2 = T_1 divided by T_2 and

P_1 divided by P_2 = T_1 divided by T_2

Most gases will expand in volume at practically the same rate with an increase in temperature, providing the pressure does not change. If the gas is confined so that its volume will remain the same, the pressure in the container will increase at about the same rate as an increase in temperature.

Charle's law formulas can be transposed into the following equations:

$V_1 T_2 = V_2 T_1$ and $P_1 T_2 = P_2 T_1$

Example: If the temperature of 2 cu ft of gas was increased from 40° F. to 120° F., what would be the new volume, if there was no change in pressure?

$V_2 = (V_1 T_2)$ divided by T_1

$V_2 = 2 \times (120 + 460)$ divided by $(40 + 460)$

$V_2 = 1{,}160$ divided by 500

$V_2 = 2.32 \text{ ft}^3$

Example: If a container holds 2 ft^3 of gas at 20 psig, what will be the new pressure in psig, if the temperature is increased from 40° F. to 120° F.?

$P_2 = (P_1 T_2)$ divided by T_1

$P_2 = (20 \text{ psig} + 14.7) \times (120 + 460)$ divided by $(40 + 460)$

$P_2 = 40.25$ psia

$P_2 = 40.25$ psia - 14.7 atmospheric pressure

$P_2 = 25.55$ psig

In numerous cases dealing with refrigerant vapor, none of the three possible variables will remain constant, and a combination of these two laws must be utilized, namely the GENERAL LAW OF PERFECT GAS. This third law is written as an equation as follows:

$(P_1 V_1)$ divided by $T_1 = (P_2 V_2)$ divided by T_2 or

$P_1 V_1 T_2 = P_2 V_2 T_1$

Note: IT MUST BE REMEMBERED THAT THE UNITS OF P AND T ARE ALWAYS USED IN THE ABSOLUTE.

Example: If a volume of 4 ft^3 of a gas at a temperature of 70° F and at atmospheric pressure is compressed to one-half its original volume and increased in temperature to 120° F, what will be its new pressure?

$P_2 = (P_1 V_1 T_2)$ divided by $(V_2 T_1)$

$P_2 = (14.7 \times 4)(120 + 460)$ divided by $2 \times (70 + 460)$

$P_2 = 34{,}104$ divided by 1,060

$P_2 = 32.17$ psia

$P_2 = 32.17$ psia - 14.7 atmospheric pressure

$P_2 = 17.47$ psig

Another relationship that must be examined is the basic relationship between pressure and boiling point for liquids. The boiling temperature of any liquid varies according to the pressure on the liquid: the higher the pressure, the higher the boiling point. It is well to remember that condensing a gas to a liquid is just the reverse process of boiling a liquid until it vaporizes, and that the same pressure and temperature relationship is required to produce either change of state.

Water boils at 80°F under a vacuum of 29 inches of mercury; at 212°F at atmospheric pressure (14.7 psi), and at 489° at a pressure of 600 psig. Refrigerants have much lower boiling points than water, under any given pressure, but these boiling points also vary according to pressure. Refrigerant R-12, for example, boils at -21.7°F at atmospheric pressure, at 0°F at 9.17 psig; at 50°F at 46.9 psig; and at 100°F at 116.9 psig. From these figures, you can see that R-12 cannot exist as a liquid at ordinary temperatures unless it is confined and put under pressure.

If the temperature of a liquid is raised to the boiling point corresponding to its pressure, and if the application of heat is continued, the liquid will begin to boil and vaporize. The vapor, which is formed, remains at the same temperature as the boiling liquid, as long as it is in contact with the liquid. The vapor cannot be superheated as long as it is in contact with liquid from which it is being generated.

There is a basic relationship between the pressure and boiling point for each liquid. The refrigeration technician must throughly understand this relationship because it is by far his most useful tool in troubleshooting a refrigeration or air conditioning system. Taking a pressure reading with a suitable gage connected to the part of the system a technician is investigating can often tell him not only whether the system is functioning properly, but what is wrong with it.

The equations that were given earlier indicate the nature of the relationship between the pressure, the volume, and the temperature of any gas. You will probably not find it necessary to use the equations themselves, but you should have a thorough understanding of the principles which they express. To summarize them:

- When the temperature is held constant, increasing the pressure on a gas will cause a proportional decrease in volume; decreasing the pressure causes a proportional increase in volume.

- When the pressure is held constant, increasing the temperature of a gas causes a proportional increase in volume; decreasing the temperature causes a proportional decrease in volume.

- When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure; decreasing the temperature causes a proportional decrease in pressure.

In this discussion of the effects of pressure on a gas, you have noted that the volume and temperature of the gas are different AFTER the pressure has been changed. It is also important to note, however, that a temperature change normally occurs in a gas WHILE the pressure is being changed. Compressing the gas raises its temperature. Allowing a gas to expand lowers its temperature. As you will see, this is an important fact in the refrigeration cycle.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the definition of pressure?

2. Describe atmospheric pressure.

3. What is the amount of pressure exerted by the atmosphere?

4. Name the most common type pressure gage used in the refrigeration field.

5. Name two types of pressure gages.

a. ______________________________

b. ______________________________

6. State the three laws that effect the pressure-temperature-volume relationship.

a. ______________________________

b. ______________________________

c. ______________________________

Work Unit 1-4. REFRIGERATION CYCLE

STATE THE PURPOSE OF A REFRIGERATION CYCLE.

STATE THE TWO DIFFERENT PRESSURES THAT EXIST IN THE CYCLE.

NAME THE TWO DIVIDING POINTS OF THE PRESSURE AREAS IN THE REFRIGERATION CYCLE.

DEFINE REFRIGERATION TON.

Looking at figure 1-19, you will see a simplified refrigeration system. By applying the theory of latent heat and pressure difference, you can visualize what is taking place to produce a low temperature.

The purpose of the refrigeration cycle is to remove unwanted heat from one place and discharge it into another. To accomplish this, the refrigerant is pumped through a completely closed system. If the system were not closed, it would use refrigerant by dissipating it into the air, however, because it is closed, the same refrigerant is used over again, each time it passes through the cycle it removes some heat and discharges it.

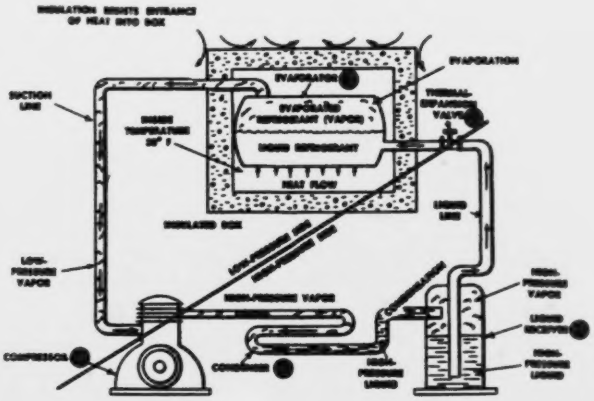

INSULATION RESISTS ENTRANCE OF HEAT INTO BOX
EVAPORATION
EVAPORATOR
SUCTION LINE
THERMAL EXPANSION VALVE
EVAPORATED REFRIGERANT (VAPOR)
LIQUID REFRIGERANT
HEAT FLOW
LIQUID LINE
INSULATED BOX
LOW-PRESSURE VAPOR
LOW-PRESSURE SIDE
HIGH-PRESSURE SIDE
HIGH-PRESSURE VAPOR
CONDENSATION
HIGH-PRESSURE VAPOR
LIQUID RECEIVER
HIGH-PRESSURE LIQUID
COMPRESSOR
CONDENSER
HIGH-PRESSURE LIQUID

Fig 1-19. Mechanical refrigeration system.

A comparable situation would be a boat that is filled with water. You want to remove the water, so you use a pail. As you scoop out the unwanted water and transfer it to the outside of the boat, you are holding onto the pail and using it over and over again as you continue to bail, see figure 1-20.

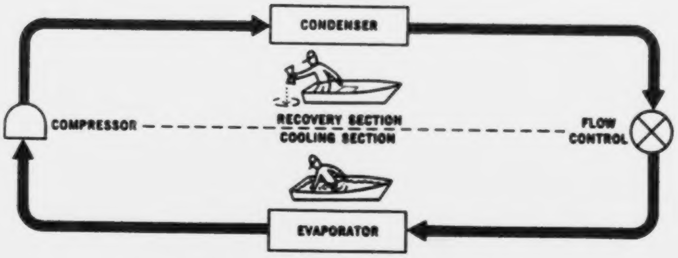


Fig 1-20. Closed cycle.

The closed cycle serves other purposes as well. It keeps the refrigerant from becoming contaminated and controls it flow, for it is a liquid in some parts of the cycle and a gas in other phases.

Let's take a look at what happens in a simple refrigeration cycle, and at the major components which comprise it. We will enlarge upon the refrigeration cycle in the study units that follow.

In the simple refrigeration system, figure 1-21, two different pressures exist in the cycle, the evaporating or low pressure in the "LOW SIDE" and the condensing or high pressure in the "HIGH SIDE." These pressures areas are separated by two dividing points, one is the metering device where the refrigerant flow is controlled, and the other is the compressor where the vapor is compressed.

At the metering device is where you start your trip through the cycle. This metering device may be an expansion valve, capillary tube, or other device that is used to control the refrigerant flow into the evaporator or cooling coil, as a low pressure, low temperature refrigerant. The expanding refrigerant evaporates (changes state) as it travels through the cooling coil, where it removes the heat from the space in which the evaporator is located.

Heat will travel from the warmer air to the coils cooled by the evaporation of the refrigerant within the system, causing the refrigerant to "boil" and evaporate, thus changing it to a vapor. This is similar to the change of state that occurs when a pan of water is boiled on the stove and the water changes to steam, except that the refrigerant boils at a much lower temperature.

This low temperature, low pressure vapor is drawn to the compressor where it is compressed into a high temperature, high pressure vapor. The compressor discharges it to the condenser, so that it can give up the heat that it picked up in the cooling coil or evaporator. The refrigerant vapor is at a higher temperature than is the air passing across the condenser (air-cooled type); therefore, heat is transferred from the warmer refrigerant vapor to the cooler air.

In this process, as the heat is removed from the vapor, a change of state takes place and the vapor is condensed back into a liquid at a high pressure and a high temperature.

The liquid refrigerant now travels to the metering device where it passes through a small opening or orifice where a drop in pressure and temperature occurs, and then it enters into the evaporator or cooling coil. As the refrigerant makes its way into the larger opening of the tubing or coil it vaporizes and it is ready to start another cycle through the system.

The refrigeration system requires some means of connecting the major components (evaporator, compressor, condenser, and metering device) justs as roads connect communities. Tubing or "lines" make the system complete and prevent the refrigerant from leaking out into the atmosphere. The suction line connects the evaporator or cooling coil to the compressor; the hot gas or discharge line connects the compressor to the condenser; and, the liquid line is the connecting tubing between the condenser and the metering device. Some systems will have receivers or storage tanks immediately after the condenser and before the metering device, where the liquid refrigerant remains until it is needed for heat removal in the evaporator.

There are many different kinds and variations of the refrigeration cycle components. For example, there are at least a half dozen different types of compressors, from the reciprocating piston through a centrifugal impeller design, but the function is the same in all cases, that of compressing the heat laden vapor into a high temperature vapor.

The same can be said of the condenser and evaporator surfaces. They can be bare pipes, or they can be finned condensers and evaporators with electrically driven fans to make the air pass through them.

There are a number of different types of metering devices used to meter the liquid refrigerant into the evaporator, depending on the size of equipment, refrigerant used, and its application.

The mechanical refrigeration system described above is essentially the same whether the system is a domestic refrigerator, a low temperature freezer, or a comfort air conditioning system. Refrigerants may be different, and the size of equipment may vary greatly, but the principles of operation and refrigeration cycle remain the same. Thus, once you understand the simple action that is taking place within the mechanical cycle, you will have come a long way toward understanding how a refrigeration system works.

Another system that will be touched on very briefly is the ABSORPTION SYSTEM; however, the main emphasis will be on the MECHANICAL SYSTEM. Although the Marine Corps no longer maintains absorption systems, you should have some understanding of such a system.

The absorption system differs from a mechanical system in that heat energy is used instead of mechanical energy to make a change in the conditions necessary to complete a cycle of refrigeration. Gas, kerosene, or an electric heating element may be used to supply the required heat energy.

From figure 1-21, you can trace the elementary cycle of an absorption system. Heat is applied to the generator or absorber from which ammonia gas is liberated and driven into the condenser, where the vapor is liquified by cooling. This liquid refrigerant is forced from the condenser to the receiver by the pressure of the vapor entering the condenser. When a sufficient amount of ammonia is driven into the condenser and receiver, heating is discontinued and the absorber cools. When the temperature of the absorber is lowered, it begins to take back the ammonia gas. The apparatus is so constructed that it can obtain this ammonia only from the cooling unit through the process of evaporation, thus lowering the temperature of the compartment that is to be cooled. As the ammonia evaporates from the cooling unit, it is replaced by liquid from the receiver. This operation will continue until the proper amount of ammonia is reabsorbed by the generator. Then, heat is again applied and a new charge of ammonia is stored in the receiver.

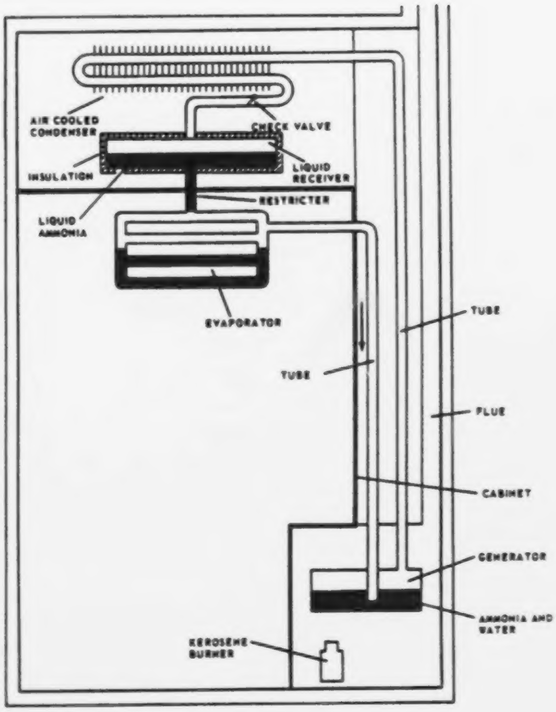

AIR COOLED CONDENSER
CHECK VALVE
INSULATION
LIQUID RECEIVER
RESTRICTER
LIQUID AMMONIA
EVAPORATOR
TUBE
TUBE
FLUE
CABINET
GENERATOR
AMMONIA AND WATER
KEROSENE BURNER

Fig 1-21. Absorption system.

In both systems, ABSORPTION and MECHANICAL, the unit which measures the amount of heat removal and thereby indicates the capacity of the refrigeration system is known as the REFRIGERATION TON. It is based on the cooling effect of 1 ton (2,000 lbs) of ice at 32°F melting in 24 hours. As you have seen, the latent heat of fusion of ice (or water) is 144 Btu's. Therefore, the number of Btu's required to melt 1 ton of ice is 144 Btu's multiplied by 2,000 which equals 288,000 Btu's. The standard refrigeration ton is defined as the transfer of 288,000 Btu's in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btu's per hour (288,000 Btu divided by 24 hours). It should be emphasized that the refrigeration ton is the standard unit of measure used to designate the heat removal capacity of a refrigeration unit, and it is not necessarily a measure of the amount of ice the unit can make in a given length of time.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the purpose of the refrigeration cycle?

____

____

2. What are the two different pressures that exist in the refrigeration cycle?

a. ______________________

b. ______________________

3. Where are the two dividing points of the pressure areas in the refrigeration cycle?

   a. ______________________________

   b. ______________________________

4. Define refrigeration ton.

   ____

   ____

5. The hot gas line connects the ____________________ and ____________________.

6. The suction line connects the ____________________ and ____________________.

SUMMARY REVIEW

In this Study Unit, you have learned the theories of the five thermal laws of refrigeration, heat, pressure, the basic refrigeration cycle, and the refrigeration ton. All these theories are important to you, as a refrigeration technician, because they will help you to understand how refrigeration equipment is able to remove heat from a given area. Some of the important things you learned and should remember are:

- Heat is energy and it cannot be destroyed or be lost, but it can be transferred from one substance to another in three ways: conduction, convection, and radiation.
- The temperature or intensity of heat can be measured. The scales that are used are Fahrenheit and Celsius (centigrade). It is possible to convert one scale to the other through the use of conversion formulas which should be memorized, as they will be important to you in your work as a refrigeration technician.
- Heat is measured in Btu's.
- Sensible and latent heat are the types of heat which effect the temperature and physical state of a substance.
- Pressure is important in that it affects the physical state of a substance in a pressure-temperature relationship.
- Pressure affects the volume of a gas, in that the pressure varies inversely with volume. If the pressure increases, the volume decreases and if the pressure decreases, the volume will increase; this happen only if the temperature remains constant.
- Pressure is measured in pounds per square inch (psi) above atmospheric pressure and inches of mercury (Hg) below atmospheric pressure. Atmospheric pressure at sea level is equal to 14.7 psia.
- Two separate systems are used to lower temperature in refrigeration, the mechanical system and the absorption system. Each system has its own cycle of operation and method of removing or transferring heat from a given area.
- A ton of refrigeration can be equated to the melting of 1 ton of ice in a 24 hour period. This equals to the removal or transfer of 288,000 Btu's. A refrigeration ton is equal to 12,000 Btu's per hour. (288,000 Btu's divided by 24 hours)

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. From a high temperature to a lower temperature
2. the pressure remains constant
3. heat
4. A high heat conductivity
5. While changing from a liquid state to a vapor state
6. a. Solid
   b. Liquid
   c. Gas or vapor

Work Unit 1-2.

1. a Heat intensity
   b. Heat quantity
2. a. Fahrenheit
   b. Celsius
3. One Btu is the amount of heat required to raise the temperature of one pound of water 1°F at sea level.
4 168 Btu's
5. 68°F
6. 26.7°C
7. Sensible heat
8. Latent heat
9. a Conduction
   b. Convection
   c. Radiation
10. Convection

Work Unit 1-3.

1. Pressure is the amount of force exerted on a substance per unit area.
2. Atmospheric pressure is the amount of force that is exerted by the air surrounding the earth.
3. 14.7 psi
4. Bourdon tube
5. a. Single function pressure gage
   b. Compound pressure gage

6. a. Boyles' Law
   b. Charles' Law
   c. General Gas Law

Work Unit 1-4.

1. To remove unwanted heat from one place and discharge it into another
2. a. Evaporating or low pressure side
   b. Condensing or high pressure side
3. a. Metering device
   b. Compressor
4. The unit which measures the amount of heat removal and thereby indicates the capacity of the refrigeration system.
5. Compressor and condenser
6. Evaporator and compressor

STUDY UNIT 2

REFRIGERANTS AND LUBRICANTS

STUDY UNIT OBJECTIVE: WITH AND WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY PRIMARY AND SECONDARY REFRIGERANTS, THE DIFFERENCES BETWEEN PRIMARY AND SECONDARY REFRIGERANTS, AND THE PROPERTIES OF REFRIGERANTS. YOU WILL IDENTIFY THE DIFFERENT MARKINGS OF COMPRESSED GAS CYLINDERS, THE TRANSFERRING AND MEASURING OF REFRIGERANTS, REFRIGERANT OILS, PROPERTIES OF REFRIGERANT OILS, VISCOSITY RATING OR REFRIGERANT OILS, AND THE SAFETY PRECAUTIONS FOR REFRIGERANTS.

Refrigerants are the vital fluids in the mechanical refrigeration system. They absorb heat from a place where it is not wanted and emit it elsewhere. The evaporation of the liquid refrigerant removes heat, which is released by the condensation of the heated vapor. Any substance that undergoes phase change from liquid to vapor and vice versa may function as the refrigerant in vapor compression type systems. However, only those substances that undergo these changes at commercially useful temperatures and pressure levels are of practical value.

It can be said that there is no "universal" refrigerant. Since mechanical refrigeration is used over a wide range of temperature, some refrigerants are more suitable for high temperature refrigeration, such as comfort cooling, than, others that operate at lower temperature ranges, such as those used for commodity storage and freezing. There are still other applications requiring even lower temperatures. The choice of a refrigerant for a particular application frequently depends on properties not related to its ability to remove heat. For example, its toxicity, flammability, density, viscosity, and availability. Thus, the selection of a refrigerant for a particular purpose may be a compromise among conflicting properties.

Work Unit 2-1. REFRIGERANT REQUIREMENTS

STATE THE PURPOSE OF A REFRIGERANT.

LIST THREE FACTORS THAT AFFECT REFRIGERANTS.

IN THE SELECTION AND USE OF REFRIGERANTS, LIST FOUR CHEMICAL PROPERTIES THAT MUST BE CONSIDERED.

IN THE SELECTION AND USE OF REFRIGERANTS, LIST FIVE IMPORTANT PHYSICAL PROPERTIES THAT MUST BE CONSIDERED.

In the process of cooling, you must have something that will effect a heat transfer. That is, something that will carry heat from one area or substance to another. To do this, you use fluids that exert a direct action on an area or substance, and that can easily change their state from a liquid to a gas and from a gas to a liquid. These fluids, called REFRIGERANTS, are heat carriers. They absorb heat at low temperatures, and when compressed to a higher temperature, they release the absorbed heat to a cooling medium, thus affecting the heat transfer.

Many different refrigerants have been used since the early days of refrigeration. Experimentation, research, and testing are still going on with various chemicals or compounds and mixtures of chemicals. At one time or another, air, butane, choroform, ether, propane, water, and other organic and inorganic compounds have been used.

With the discovery of new chemicals and compounds, the practical advantages and disadvantages of each of the refrigerants in use were carefully appraised. Therefore, consideration is now given to the characteristics of various refrigerants , both from a chemical and a physical standpoint. The availability and cost of each refrigerant is also of great importance.

Refrigerants in common use today are fluids that are affected by HEAT, TEMPERATURE, and PRESSURE in a manner similar to water. Some of these refrigerants are better that others, but the perfect refrigerant has yet to be discovered. As you know, an automatic mechanism, such as a refrigeration system ,should be safe. Therefore, the refrigerants selected should be as close to perfect as possible, and still they should be able to accomplish their cooling job efficiently and effectively. Refrigerants should be NONPOISONOUS, NONFLAMMABLE, NONEXPLOSIVE, and have a LOW BOILING POINT. They should also be NONCORROSIVE so that the more common metals may be used in the construction of component parts. A good refrigerant is STABLE and not easily decomposed or subject to chemical reaction with lubricants used in the system. It is also desirable to keep normal operating pressure as close as possible to atmospheric pressures. Great differences in pressure would cause the system to over work. This would cause leaks and would cut down on the efficiency and life expectancy of the compressor and valves.

Remember that each refrigerant reacts to the effect of TEMPERATURE and PRESSURE. Each has a critical temperature and pressure. The critical temperature of a refrigerant is the maximum temperature at which it can be liquefied. The critical pressure of a refrigerant is the maximum pressure at which it can operate in a system without causing leaks and without causing the compressor to overwork. Therefore, the critical pressure must be well above a system's normal condensing pressure, and the critical temperature must be well above the system's normal condensing temperature. In either case, if they (CRITICAL TEMPERATURE or PRESSURE) are only a little above normal pressure and temperature, it will cause overworking of the compressor and excessive power usage.

In the selection and use of refrigerants the following characteristics must be taken into consideration:

- CHEMICAL PROPERTIES:
  - Flammability
  - Explosiveness
  - Toxicity
  - Stability
- PHYSICAL PROPERTIES:
  - Boiling point
  - Freezing point
  - Specific volume
  - Density
  - Critical pressure
  - Critical temperature
  - Latent heat content
  - Oil miscibility
  - Leak detection

These properties, both chemical and physical, will be examined more closely so that you will understand each of their characteristics.

- FLAMMABILITY and EXPLOSIVENESS: When a system is operating satisfactorily, there is no need to worry about its refrigerant. However, should a fire, due to an outside source, occur in the vicinity of any refrigeration component, there is always the danger that the fire might spread. With a fire, there is also the possibility of an explosion if a refrigerant escapes from ruptured lines or tubes.

If a leak occurs or if repairs must be made to some component, the flammability and possible explosiveness and toxicity of the refrigerant must be taken into consideration. Even though the system may be evacuated, all of the refrigerant contained in the receiver or condenser receiver, the brazing, soldering or welding that may be necessary in the repair or replacement of a component may present hazards, because enough vapor may remain in the component or connecting lines to cause danger from the heat or flame of the repair equipment.

Since hydrocarbon refrigerants, such as butane (R-600), ethane (R-170), and propane (R-290), are highly flammable and explosive, proper care must be taken when working with an open flame around a system using any of these refrigerants. The halocarbon refrigerants are considered to be nonflammable, but some become toxic when exposed to flames. Among these are trichloromonofluoromethane (R-11), dichlorodifluoromethane (R-12), and monochlorodifluoromethane (R-22). R-502, which is an azeotrope refrigerant, is a mixture of 48.8% R-22 and 51.2% R-115 (chloropentafluoroethane), and is nonflammable.

Since there are many "tongue-twisters" in the chemical names of refrigerants, it was a relief when a numbering system was developed. The numbering system, which is more commonly used today instead of the chemical names, is customarily preceded by the trade name of the manufacturer, but, in general practice, the number is preceded by the term refrigerant or just the letter "R."

This numbering system for refrigerants was developed by the DuPont Company, the first to market many of the new breeds of refrigerants. At the outset, the letter "F" (for freon, a registered DuPont trademark) preceded the numbers. Later, as there were other producers of halocarbon refrigerants, DuPont made its numbering system available to the entire industry. As was stated previously, refrigerants now are known by the letter "R" and number, such as R-12, R-22, etc.

● TOXICITY: The Underwriters Laboratories has conducted extensive tests on guinea pigs to illustrate the toxicity of all refrigerants; the guinea pigs quickly showed the effects of inhaling toxic gases and vapors. It should be noted that humans were not used in these tests.

Air is the exception to the rule that all gaseous substances are, to some degree, toxic. Of course there are various degree of toxicity. Carbon dioxide is inhaled whenever people breathe, and it is therefore harmless to humans up to a certain level in the surrounding atmosphere. However, an individual exposed to an atmosphere containing about 8% to 10% carbon dioxide or more would soon become unconscious.

The test made by the Underwriters Laboratories pertained to the type of chemicals or compound, the percent of the vapor being tested in the given atmosphere, and the duration of the time in which the subject was exposed to or had breathed the mixture. Underwriters Laboratories have devised a numbers classification that ranges from 1 to 6; the lowest number designates the most toxic and dangerous refrigerant, and the highest number designates the least toxic refrigerant. Figure 2-1 lists the classification of some refrigerants and the concentration and length of exposure that leads to serious injury.

GROUP	LIMITATIONS	REFRIGERANTS
1	Concentration of gases or vapors about 0.5-1% for about 5 min is capable of producing serious injury. or death.	Sulphur Dioxide
2	Concentration of gases or vapors about 0.5-1% for about 30 min is capable of producing serious injury or death.	Ammonia
3	Concentration of gases or vapors about 3-2.5% for about 1 hr is capable of producing serious injury or death.	Chloroform
4	Concentration of gases or vapors about 2-2.5% for about 2 hrs is capable of producing serious injury or death.	Methyl Chloride
5	Gases or vapors that are less toxic than Group 4 yet more toxic than those in Group 6.	R-11, 22, 502, Butane, Propane
6	Concentration of gases or vapors about 20% for periods of about 2 hrs has apparently no injury.	R-12, 114

Fig 2-1. Classification of gases and vapors by Underwriters Laboratories.

The National Refrigeration Safety Code (NRSC) divides refrigerants into three groups: group 1 is the safest; group 2 is somewhat flammable and toxic; and group 3 is extremely flammable. The National Board of Fire Underwriters (NBFU) uses six classes; they are similar to the Underwriters Laboratories, however, class 1 is the most toxic one and class 6 the least toxic. Refer to figure 2-2 for a comparison.

N. B. F. U. Toxicity Classification						
N. R. S. C.	**Class**					
	Most toxic					**Least toxic**
Group 1	**1**	**2**	**3**	**4**	**5**	**6**
F-12						X
Kulene-131						X
F-114						X
Carbon dioxide					X	
F-22					X	
Carrene #1				X		
F-113				X		
Methylene chloride				X		
F-21				X		
F-11				X		
Group 2						
Dichloroethylene				X		
Ethyl chloride				X		
Methyl chloride				X		
Methyl formate			X			
Ammonia		X				
Sulfur dioxide	X					
Group 3						
Butane					X	
Isobutane					X	
Ethane					X	
Propane					X	

Fig 2-2. Group and toxicity classification.

- CRITICAL PRESSURES and TEMPERATURES: As was stated previously, each refrigerant reacts to the effects of temperature and pressure. Every refrigerant, whether a single element or a mixture of elements (a compound), has among its characteristics a pressure above which it will remain as a liquid, even though more heat is added. Each element or compound, has a temperature above which it cannot remain or exist in a liquid state, regardless of the pressure exerted on it. These points are the vapor pressure and the temperature, respectively, of the refrigerant. Some of these are shown in figure 2-3.

REFRIGERANT	CRITICAL PRESSURE PSIA	CRITICAL TEMPERATURE °F
R-12	596.9	233.6
R-22	721.9	204.6
R-502	591	179.9

Fig 2-3. Critical pressures and temperatures of some refrigerants.

The pressures and temperatures shown in figure 2-3 are well above the pressures that can be expected to occur in the condenser, and also above the temperatures that accompany these operating pressures. These refrigerants are chemically stable in the ranges specified. They do not have a tendency, under normal conditions, to react with any material used in the manufacture of the components in the refrigeration system, nor do they ordinarily break down chemically. If the refrigerant in a system is unstable, it quickly becomes useless, since a chemical reaction will change the original characteristics or properties of the refrigerant. Decomposition of the refrigerant will add noncondensable gases, thus causing abnormal pressures and temperatures within the system, and the resulting sludge may cause mechanical troubles.

- PHYSICAL PROPERTIES: It has been stated earlier that a refrigerant absorbs much more heat when it changes its state from a liquid to a vapor, than when it absorbs the heat as a liquid or as a vapor. Therefore, the BOILING POINT of a refrigerant is of great importance, for it must readily evaporate below temperatures of the product or space which is to be cooled. Refrigerants that do not have a relatively low boiling point require that the compressor be operated with a deep vacuum.

The FREEZING POINT of a refrigerant is another important property, particularly in extremely low temperature applications. This point should be sufficiently lower than any anticipated evaporator temperature

The LATENT HEAT CONTENT of the selected refrigerant usually is high, which is a desirable characteristic for large capacity systems. With a high latent heat content, less refrigerant is circulated for each ton of refrigeration effect produced; therefore, a compressor of lower horsepower could be used. In systems of low capacity, the use of a refrigerant with a low latent heat content will require the circulation of more refrigerant than those with a higher latent heat content. Such a refrigerant will also make the control of the system easier, since less sensitive control devices are needed in a system that circulates a larger amount of refrigerant.

The DENSITY and SPECIFIC VOLUME of a refrigerant are two properties that have a reciprocal relationship. When comparing refrigerant for different applications, advantages and disadvantages must be taken into consideration. In order to utilize smaller lines, tubes, or refrigerant pipes (these terms are used interchangeably), a high-density, low specific volume refrigerant should be used. Such a system costs less to construct and install. In some commercial installations where there is a considerable vertical distance between the major components of the system, less pressure is required to circulate the refrigerant through the components and piping.

Low OIL SOLUBILITY or MISCIBILITY is also an important characteristic of a refrigerant, but it can cause oil return problems, if it is too low. Solubility or miscibility is the capacity of the refrigerant in its liquid state to mix with oil necessary for the lubrication of the moving parts in the compressor. The oil will circulate with a high soluble refrigerant in a liquid state from the compressor and/or receiver, through the liquid line and the metering device and into the compressor.

Since the refrigerant vaporizes in the evaporator, a different situation exists; oil and refrigerant vapor do not mix readily. The oil circulating through the system can continue on its way to the compressor only if the vapor is moving rapidly enough to entrain the oil and carry it along through the suction line to the compressor crankcase. If the vapor lines, either suction or hot gas, run in a horizontal path, it is customary to size them so that the vapor travels at a velocity rate not less than 750 fpm (feet per minute). When the vapor lines are run vertically upward, the velocity of the vapor should not be less than 1,500 fpm to assure that the oil will travel up the vertical line. An example of this would be an evaporator located somewhere beneath the compressor or condenser.

- LEAK DETECTION: Leak detection was and is fairly easy when ammonia or sulphur dioxide is being used, since their peculiar odors are discernible from all others. Yet, depending strictly upon odors for leak detection of these refrigerants may be deceiving as well as dangerous. Frequently, in order to pinpoint a leak when there is quite a bit of vapor in the air, a solution of soap and water is swabbed or wiped over the suspected area. When a system is still under pressure, bubbles will form in the immediate area of a leak. This means of leak detection should not be used if a section of the system is under a vacuum, for the soap and water solution might be drawn into the system.

Figure 2-4 shows a halide leak detector, which has been used successfully on systems with halogenated refrigerants for a number of years. This leak detector consists of two major components: the cylinder containing gas and the detector unit. The principle involved is that air is drawn through the search hose and across a copper reactor plate, which has been heated red hot from the gas flame. When the search hose is manipulated so that it comes in contact with the leaking refrigerant vapor, gas is drawn through the hose. When the gas or vapor comes in contact with the flame and the reactor plate, the flame changes to a bluish green or violet color. For most leaks, this type of detector works satisfactorily; however, it is not as sensitive as the electronic leak detector shown in figure 2-5. This type of detector is capable of detecting leaks as small as 0.5 ounce per year. Its use is growing in the field because of its sensitivity. This detector contains an internal pump that draws air into the probe and hose or tube. If there is any halogenated gas in the air drawn across the electrodes in the sensing element, a built in signal light will flash frequently as shown in figure 2-6. The rate of the flashing will increase depending upon the amount of refrigerant vapor in the air.

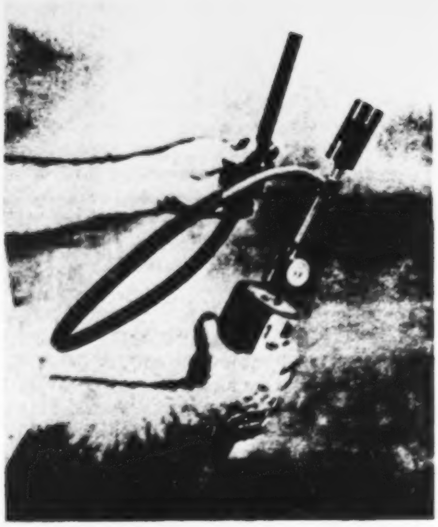


Fig 2-4 Halide leak detector.

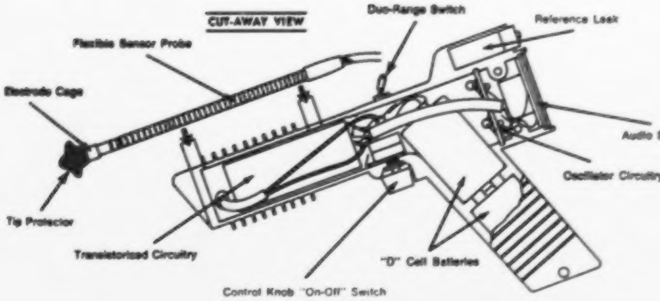

CUT-AWAY VIEW
Duo-Range Switch
Reference Leak
Flexible Sensor Probe
Electrode Cage
Audio Signal
Oscillator Circuitry
Tip Protector
Transistorized Circuitry
"D" Cell Batteries
Control Knob "On-Off" Switch

Fig 2-5. Electronic leak detector.
(Battery operated)

POWER
CORD
PROBE

Fig 2-6. Electronic leak detector.
(Electric)

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the purpose of the refrigerants used in mechanical refrigeration systems?

   ____

2. List the three factors that affect refrigerants.

   a. ______________________

   b. ______________________

   c. ______________________

3. List four chemical properties of a good refrigerant that must be considered in the selection and use of refrigerants.

   a. ______________________

   b. ______________________

   c. ______________________

   d. ______________________

4. List five important physical properties of a refrigerant that must be considered when selecting and using refrigerants.

   a. ______________________

   b. ______________________

   c. ______________________

   d. ______________________

   e. ______________________

Work Unit 2-2. PRIMARY AND SECONDARY REFRIGERANTS

DEFINE PRIMARY REFRIGERANTS.

IDENTIFY SECONDARY REFRIGERANTS.

SPECIFY THE MOST PROMINENT REFRIGERANTS IN USE TODAY.

DETERMINE THE CHEMICAL AND PHYSICAL PROPERTIES OF R-12 REFRIGERANT.

DETERMINE THE CHEMICAL AND PHYSICAL PROPERTIES OF R-22 REFRIGERANT.

DETERMINE THE CHEMICAL AND PHYSICAL PROPERTIES OF R-11 REFRIGERANT.

DETERMINE THE CHEMICAL AND PHYSICAL PROPERTIES OF R-502 REFRIGERANT.

In refrigeration, you will deal with two types of refrigerants: PRIMARY and SECONDARY. Your main concern in this course will be with primary refrigerants but secondary refrigerants will also be discussed briefly.

Secondary refrigerants are agents such as air, water, and brine. They are in themselves not refrigerants and cannot be used in systems requiring primary refrigerants. Secondary refrigerants are cooled and passed over or around an area that needs cooling. They pick up heat from that area and then return to the cooling component of the primary refrigerant system. They are again cooled and the cycle starts over. These agents may be used as brine or water sprays or they may be passed over the system by the use of a blower or fan. Remember, secondary refrigerants cannot be used in the primary system.

Primary refrigerants are fluids used in air-conditioning and refrigeration mechanical systems that absorb heat from an area to be cooled and release this heat outside of the cooled or refrigerated area. Mechanical refrigeration equipment in use today is dependent upon the primary refrigerant to perform its task in the removal of heat. The refrigerant pumped through the system is recycled constantly. It is NEVER consumed. Replacement is only necessary in the event of a leak, or when repairs are required by the system or equipment.

There are numerous primary refrigerants in use today; however, you, as a refrigeration technician in the Marine Corps, will be concerned with only four of them. Of the four, you will be working extensively with two refrigerants, R-12 and R-22. The other two refrigerants, R-11 and R-502, are refrigerants that you might come across if you are assigned to a base maintenance organization.

The majority of the equipment used by the Marine Corps requires the use of R-12 (Dichlorodifluoromethane) and R-22 (Monochlorodifluoromethane). Some of the domestic and commercial refrigeration equipment, usually large capacity units, require the use of R-11 (Trichloromonofluoromethane) and R-502 (Azeotropic mixture of 48.8% of R-22 and 51.2% of R-115).

Due to the extensive use of R-12 and R-22 by the Marine Corps, you will begin your study of primary refrigerants with these two. After you have completed this study, you will be introduced to R-11 and R-502 refrigerants by a brief discussion.

Because the refrigeration industry was in need of a safe refrigerant with desirable characteristics, the fluorocarbon families of refrigerants were developed. The most prominent refrigerants in use today are part of the fluorocarbon family of refrigerants. They are R-12 and R-22. R-500, an azeotropic refrigerant so called because it is a combination of two refrigerants, was developed as a substitute for R-12, and it has a greater refrigeration capacity than R-12 for comparable temperature and displacement. The cooling capacity of a unit will increase approximately 15% when R-12 is replaced with R-500.

R-12 was developed from carbon tetrachloride. Carbon "tet" as it was known in the industry is used as a cleaning solvent. Because it contains no moisture it is ideal for cleaning compressor parts and in flushing a system. To develop R-12 from carbon tet, two of the chloride atoms were replaced with two flurine atoms. The resulting compound was dichlorodifluoromethane, better known as R-12. Because of its high stability and low operating pressures and temperatures R-12 is an ideal refrigerant.

- R-12 (Dichlorodifluoromethane) - Its characteristics are as follows: R-12 is a very popular refrigerant. It is colorless, almost odorless liquid with a boiling point of -21.7° F. at atmospheric pressure. It remains a liquid at ordinary temperature if under a pressure of 70 to 75 psig (pounds per square inch gage). In concentrations higher than 20% by volume in air, it has an odor that resembles carbon tetrachloride. It is nonirritating to eyes, nose, throat, and lungs in vapor or air mixtures. R-12 vapor is nonpoisonous, but it will not support breathing. It produces mild anesthesia if inhaled in sufficient quantities. Care must be taken to keep R-12 from coming into contact with the eyes, or freezing may result. The only hazard to using R-12 is the health hazard; however, in order for it to become a health hazard, there must be an accumulated leakage in a nonventilated space, or the vapors must come in direct contact with a high temperature open flame (approximately 1,000° F). If either of these instances occur, you will notice a pungent and irritating odor which is ample warning to prevent your health from becoming endangered.

R-12 is a NONTOXIC, NONCORROSIVE, NONIRRITATING, and NONFLAMMABLE refrigerant.

Chemically, it is inert at ordinary temperatures and thermally stable to above 800° F (427° C). This temperature is well above the safe operating temperatures of most refrigerating mechanism materials and lubricants. A table of R-12 properties is shown in figure 2-7.

	PRESSURE		VOLUME VAPOR	DENSITY LIQUID	HEAT CONTENT BTU/LB.	
Temp. F.	Psia	Psig	Cu. Ft./Lb.	Lb./Cu. Ft.	Liquid	Vapor
-150	0.154	29.61*	178.65	104.36	-22.70	60.8
-125	0.516	28.67*	57.28	102.29	-17.59	63.5
-100	1.428	27.01*	22.16	100.15	-12.47	66.2
- 75	3.388	23.02*	9.92	97.93	- 7.31	69.0
- 50	7.117	15.43*	4.97	95.62	- 2.10	71.8
- 25	13.556	2.32*	2.73	93.20	3.17	74.56
- 15	17.141	2.45	2.19	92.20	5.30	75.65
- 10	19.189	4.49	1.97	91.69	6.37	76.2
- 5	21.422	6.73	1.78	91.18	7.44	76.73
0	23.849	9.15	1.61	90.66	8.52	77.27
5	26.483	11.79	1.46	90.14	9.60	77.80
10	29.335	14.64	1.32	89.61	10.68	78.335
25	39.310	24.61	1.00	87.98	13.96	79.9
50	61.394	46.70	0.66	85.14	19.51	82.43
75	91.682	76.99	0.44	82.09	25.20	84.82
86	108.04	93.34	0.38	80.67	27.77	85.82
100	131.86	117.16	0.31	78.79	31.10	87.03
125	183.76	169.06	0.22	75.15	37.28	88.97
150	249.31	234.61	0.16	71.04	43.85	90.53
175	330.64	315.94	0.11	66.20	51.03	91.48
200	430.09	415.39	0.08	60.03	59.20	91.28

* Inches of mercury below one atmosphere.

Fig 2-7. Properties of refrigerant R-12.

R-12 has a relatively low latent heat value. In the smaller refrigerating machines this is an advantage. The large amount of refrigerant circulated will permit the use of less sensitive and more positive operating and regulating mechanisms. It is used in reciprocating, rotary, and large centrifugal compressors. It operates at a low but positive head and back pressure and with a good volumetric efficiency.

As shown in figure 2-7, R-12 has a pressure of 26.5 psia or 11.8 psi at 5° F (-15° C), and a pressure of 180° psia, 93.3 psi at 86° F (30° C). The latent heat content of R-12 at 5° F is 68.2 Btu/lb.

Leak detection of this refrigerant may be made by several means:

- A soap and water solution
- A halide torch
- An electronic leak detector

Water is only slightly soluble in R-12. At 0° F, it will only hold six parts per million by weight. The solution formed is only very slightly corrosive to any of the common metals used in refrigeration construction. The addition of mineral oil to the refrigerant has no effect upon the corrosive action, except to lessen the amount of discoloration caused by the free water. R-12 is more susceptible to moisture when compared to R-22. R-12 is soluble in oil down to -90° F (-68° C). This helps the oil flow in very cold evaporators. The oil will begin to separate at this temperature, and because it is lighter than the refrigerant, it will collect on the surface of the liquid refrigerant.

- R-22 (Monochlorodifluoromethane) - Its characteristics are as follows: R-22 is a man-made refrigerant developed for refrigeration installations that need low evaporating temperatures. It is a versatile refrigerant that operates at a higher system pressure, but in exchange it has lower compressor displacement requirements. It is used most frequently in most packaged air-conditioners like room and window air conditioners, and it is popular in central cooling units and heat pumps. This refrigerant is a NONTOXIC, NONCORROSIVE, NONIRRITATING, and NONFLAMMABLE synthetic chemical specially designed for refrigeration installations that have a very low temperature cooling units, such as a fast freezing unit that maintains temperatures of -20° to -40° F (-29° to -40° C). It is not necessary to use R-22 at below atmospheric pressures in order to obtain these low temperatures.

This refrigerant has a boiling point of -40° F (-41° C) at atmospheric pressure. It has a latent heat content of 93.21 Btu/lb at 5° F (-15° C). The normal head pressure at 86° F is 172.87 psia, 158 psi, as shown in figure 2-8. The evaporator pressure is 43 psia or 28 psi at 5° F.

Water mixes better with R-22 than R-12 by a ratio of 3 to 1 or 19.5 parts per million by weight. Water must be kept at a minimum, and driers (desiccants) should be used to remove most of the moisture.

It should be noted that R-22 has good solubility in oil down to 16° F (-9° C). However, the oil remains fluid enough to flow down the suction line at temperatures as low as -40° F. At this point, the oil will begin to separate.

Leak detection for this refrigerant is the same as for R-12; a soap and water solution, a halide torch, or an electronic leak detector may be used.

	PRESSURE		VOLUME VAPOR	DENSITY LIQUID	HEAT CONTENT BTU/LB.	
Temp. F.	Psia	Psig	Cu. Ft./Lb.	Lb./Cu. Ft.	Liquid	Vapor
-150	0.272	29.37*	141.23	98.24	-25.97	87.52
-125	0.886	28.12*	46.69	96.04	-20.33	90.43
-100	2.398	25.04*	18.43	93.77	-14.56	93.37
- 75	6.610	18.50*	8.36	91.43	- 8.64	96.29
- 50	11.674	6.15*	4.22	89.00	- 2.51	99.14
- 25	22.086	7.39	2.33	86.48	3.83	101.88
- 15	27.865	13.17	1.87	85.43	6.44	102.94
- 10	31.162	16.47	1.68	84.90	7.75	103.46
- 5	34.754	20.06	1.52	84.37	9.08	103.96
0	38.657	23.96	1.37	83.83	10.41	104.47
5	42.888	28.19	1.24	83.28	11.75	104.96
10	47.464	32.77	1.13	82.72	13.10	105.44
25	63.450	48.75	0.86	81.02	17.22	106.84
50	98.727	84.03	0.56	78.03	24.28	108.95
75	146.91	132.22	0.37	74.80	31.61	110.74
86	172.87	158.17	0.32	73.28	34.93	111.40
100	210.60	195.91	0.26	71.24	39.27	112.11
125	292.62	277.92	0.18	67.20	47.37	112.88
150	396.19	381.50	0.12	62.40	56.14	112.73

*Inches of mercury below one atmosphere.

Fig 2-8. Properties of refrigerant R-22.

- R-11 (Trichloromonofluoromethane) - This refrigerant is a synthetic chemical product which can be used as a refrigerant. It is STABLE, NONFLAMMABLE, and NONTOXIC. It is different from R-12 and R-22 in that it is considered to be a low pressure refrigerant; it has a low-side pressure of 24 inch vacuum at 5° F, and a high-side pressure of 18.3 psia at 86° F. The latent heat content at 5° F is 84.0 Btu/lb. This refrigerant is extensively used in large centrifugal compressor systems. As much as 35 lbs of this refrigerant may be used for each 1000 ft^3 of air conditioned space. This would accommodate a room of about 10 ft by 12.5 ft by 8 ft.

It is often used by the service technician as a flushing agent for cleaning the internal parts of a refrigerator compressor when overhauling the system. It is useful after a system has had a motor burnout or a great deal of moisture has accumulated in the system. By flushing the moisture from the system with R-11, evacuation time is shortened. R-11 is one of the safest cleaning solvents that can be used for this purpose. This refrigerant will remain a liquid at temperatures, at atmospheric pressure, up to 70° F.

- R-502 (Azeotropic mixture) - Refrigerant R-502, as was stated earlier, is an azeotropic mixture of 48.8% of R-22 and 51.2% of R-115. It is a NONFLAMMABLE, NONCORROSIVE, practically NONTOXIC liquid. A good refrigerant for obtaining medium and low temperatures, it is suitable where temperatures vary from 0° to -60° F. It is often used in frozen food lockers, frozen food processing plants, frozen food display cases and in storage units for frozen foods and ice cream. It is only used with reciprocating compressors. It combines many of the good properties of both R-12 and R-22. It gives a machine the approximate capacity of R-22 with approximately the condensing temperature of a system using R-12.

This refrigerant's relatively low condensing pressure and temperature increase the life of the compressor valves and other parts. Better lubrication is possible because of the increased viscosity of the oil at the lower condensing temperature. Because of the lower condensing pressure, it is possible to eliminate the liquid injection to cool the compressor. This is often necessary with R-22.

The boiling point of R-502 is -50.1° F at atmospheric pressure. Condensing pressure is 198.9 psia or 175.1 psi at 86° F. Its evaporating pressure at 5° F is 50.68 psia or 35.99 psi. Its latent heat content at -20° is 72.5 Btu/lb.

R-502 has a fair solubility in oil above 180° F. Below this temperature, the oil tries to separate and tends to collect on the surface of the liquid refrigerant. However, oil is carried back to the compressor at temperatures down to -40° F. Sometimes, special devices are used to return the oil to the compressor.

The fluorocarbon (halogen) family of refrigerants consists of two groups: those of the methane group such as R-11, R-12, R-13, R-14, R-21, and R-22 and those of the ethane group such as R-113 and R-114. A third group of refrigerants are called azeotropic refrigerants. Any compound refrigerant that is composed of two or more refrigerants is an azeotropic refrigerant. An important characteristic of such a compound is it STABILITY.

All fluorocarbon refrigerants have one thing in common, a low boiling point. The lower boiling point, the faster the vaporization. The refrigeration cycle is based upon the ability of a refrigerant to evaporate and be reclaimed using the compressor and condenser. The boiling point of a refrigerant generally indicates its best use. The temperature demand in relation to the boiling point helps to determine the right refrigerant for a particular use.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are primary refrigerant?

____

2. Which of the following are classified as secondary refrigerants?

   a. Air, R-12, and brine

   b. Brine, air, and azeotropic

   c. Water, air, and brine

   d. Fluorocarbon, halogen, and azeotropic

3. Select the two most prominent refrigerants in use today by the Marine Corps.

   a. R-12 and R-115

   b. R-22 and R-114

   c. R-11 and R-502

   d. R-12 and R-22

4. At atmospheric pressure, what is the temperature at which refrigerant R-12 will boil?

   a. -21.7° F

   b. -28.7° C

   c. -40° F

   d. 38° F

   e. 70 to 75° F

5. R-12 is an ideal refrigerant because of its high ____________________ and low operating ____________________.

6. If you were to enter a nonventilated area that contained a refrigeration system and were to smell an odor that resembled carbon tetrachloride, what would you suspect?

   a. That something was burning.

   b. That the area contained a high concentration, at least 20% by volume, of R-11.

   c. That the area contained a concentration of R-22.

   d. That the area contained a concentration, higher than 20% by volume, of R-12.

7. R-22 is used in units that can maintain temperatures as low as ________________.

   a. 32° to 0° F

   b. 0° to -20° F

   c. -20° to -40° F

   d. -40° to -60° F

8. Refrigerant R-22 has a boiling point of ___________ at atmospheric pressure.

9. What is the evaporator's absolute pressure at 5° F, in a unit that uses R-22?

   a. 28.19 psia

   b. 42.88 psia

   c. 47.464 psia

   d. 63.45 psia

10. What are the methods for detecting leaks in units that use both R-12 and R-22?

    ____

    ____

11. Besides being a refrigerant, R-11 is often used by the refrigeration technician as a ______________________________.

12. What is the low-side pressure at 5° F of a unit that uses R-11 as a refrigerant?

    ____

13. R-502 has a boiling point of ______________ at atmospheric pressure.

14. R-502 is used only with _________________________ type compressors.

15. What is the one thing that all fluorocarbon (halogen) refrigerants have in common?

    ____

Work Unit 2-3. REFRIGERANT TABLES

GIVEN A REFRIGERANT TABLE FOR R-12, DETERMINE CONDENSING PRESSURE, EVAPORATOR PRESSURE, AND REFRIGERATING EFFECT.

GIVEN A REFRIGERANT TABLE FOR R-22, DETERMINE DENSITY, TOTAL HEAT CONTENT, AND ABSOLUTE PRESSURE.

GIVEN A TYPICAL REFRIGERATION SYSTEM, DETERMINE THE QUANTITY OF REFRIGERANT IN POUNDS PER HOUR REQUIRED TO OBTAIN THE DESIRED COOLING LEVEL.

A refrigerant is a carrier of heat in a refrigeration system; consequently, it is found in different parts of the system in different physical states. To determine the pressure, density, volume, heat content and latent heat corresponding to certain temperatures found in various sections of the system, you use REFRIGERANT TABLES (Tables I and II). These tables have been compiled for each of the most commonly used refrigerants; they give all the information pertinent to that refrigerant at certain temperatures. As a refrigeration technician, you need not have a full understanding of all information that can be extracted from these standard tables; however, information regarding temperature and pressure can be found quickly by referring to these tables.

The pressures and temperatures shown in columns 1, 2, and 3 of each table are related in such a way that each pressure-temperature combination represents the boiling point or the condensing point of the refrigerant. It must be remembered that the boiling point of a liquid and the condensing point of the vapor are exactly the same at any given pressure. For practical purposes, because icemaking equipment and extremely low temperature cold storage systems must be included, the tables start at -40° F. Because R-12 boils at approximately -21.7° F, it should be noted that the pressures below that temperature are negative and represent a partial vacuum. That is, those pressures are below standard atmospheric pressure of 14.7 psia.

As was discussed earlier, in refrigeration you will be dealing with two types of pressures: GAGE and ABSOLUTE. Pressure is an indication of the action of a force on a surface. At sea level, the pressure of the atmosphere is 14.7 psia. The ordinary pressure gage reads only the pressure which exceeds atmospheric pressure. This is called GAGE PRESSURE and is read in pounds per square inch. ABSOLUTE PRESSURE is found by adding the atmospheric pressure to the gage pressure. Referring to Tables I and II, notice that the absolute pressure in column 2 is 14.7 pounds higher than the gage pressure in column 3. In normal practice, gage pressure is used. A VACUUM GAGE indicates pressure below atmospheric, and the reading is expressed in inches of mercury (shown by asterisks in column 3).

Referring to Tables I and II, examine each column. Column 1 and 9 give the temperatures at 2° intervals. Column 2 and 3 list the absolute and gage pressures for each temperature at which the refrigerant will either boil or condense. Columns 4 and 5 show the density or weight of the liquid refrigerants and refrigerant vapor, in pounds per cubic foot. Column 6 shows the heat content, in Btu's per pound, of liquid refrigerant which must be added to raise the temperature of 1 lb of liquid refrigerant from -40° F to the temperature in column 1 or 9. Column 7 shows the amount of heat required to change 1 lb of refrigerant from a liquid at the temperature in column 1 or 9 to a vapor at the same temperature. Column 8 shows the total amount of heat needed to raise 1 lb of refrigerant from -40° F to the temperature in column 1 or 9, and then vaporize it at the same temperature.

Evaporating and condensing temperatures are determined at the design stage of the equipment. For example, in an air conditioning system the evaporator temperature may be 40° F and the condensing temperature may be 105° F. However, in a cold storage plant evaporator, temperatures may be as low as -10° F, with the discharge temperatures varying from 95° to 110° F. Thus, depending on the degree of cooling desired and the type of equipment used, the evaporating and condensing temperatures become somewhat fixed.

Table I. Properties of saturated refrigerant R-12.

Temp. °F.	Pressure		Density lb/cu ft		Heat content above —40°F. Btu/lb			Temp. °F.
	psia	psig	liquid	vapor	liquid	latent	total of vapor	
col. 1	col. 2	col. 3	col. 4	col. 5	col. 6	col. 7	col. 8	col. 9
—40	9.3076	10.9709**	94.661	0.25606	0	72.913	72.913	—40
—38	9.8035	9.9611**	94.469	0.27084	0.4215	72.712	73.134	—38
—36	10.320	8.909**	94.275	0.28411	0.8434	72.511	73.354	—36
—34	10.858	7.814**	94.081	0.29788	1.2659	72.309	73.575	—34
—32	11.417	6.675**	93.886	0.31216	1.6887	72.106	73.795	—32
—30	11.999	5.490**	93.690	0.32696	2.1120	71.903	74.015	—30
—28	12.604	4.259**	93.493	0.34231	2.5358	71.698	74.234	—28
—26	13.233	2.979**	93.296	0.35820	2.9601	71.494	74.454	—26
—24	13.886	1.649**	93.098	0.37466	3.3848	71.288	74.673	—24
—22	14.564	0.270**	92.899	0.39171	3.8100	71.081	74.891	—22
—20	15.267	0.571	92.699	0.40934	4.2357	70.874	75.110	—20
—18	15.996	1.300	92.499	0.42758	4.6618	70.666	75.328	—18
—16	16.753	2.057	92.096	0.44645	5.0885	70.456	75.545	—16
—14	17.536	2.840	91.893	0.46595	5.5157	70.246	75.762	—14
—12	18.348	3.652	92.298	0.48611	5.9434	70.036	75.979	—12
—10	19.189	4.493	91.689	0.50693	6.3716	69.824	76.196	—10
— 8	20.059	5.363	91.485	0.52843	6.8003	69.611	76.411	— 8
— 6	20.960	6.264	91.280	0.55063	7.2296	69.397	76.627	— 6
— 4	21.891	7.195	91.074	0.57354	7.6594	69.183	76.842	— 4
— 2	22.854	8.158	90.867	0.59718	8.0898	68.967	77.057	— 2
0	23.849	9.153	90.659	0.62156	8.5207	68.750	77.271	0
2	24.878	10.182	90.450	0.64670	8.9522	68.533	77.485	2
4	25.939	11.243	90.240	0.67263	9.3843	68.314	77.698	4
6	27.036	12.340	90.030	0.69934	9.8169	68.094	77.911	6
8	28.167	13.471	89.818	0.72687	10.250	67.873	78.123	8
10	29.335	14.639	89.606	0.75523	10.684	67,651	78.335	10
12	30.539	15.843	89.392	0.78443	11.118	67.428	78.546	12
14	31.780	17.084	89.178	0.81449	11.554	67.203	78.757	14
16	33.060	18.364	88.962	0.84544	11.989	66.977	78.966	16
18	34.378	19.682	88.746	0.87729	12.426	66.750	79.176	18
20	35.736	21.040	88.529	0.91006	12.863	66.522	79.385	20
22	37.135	22.439	88.310	0.94377	13.300	66.293	79.593	22
24	38.574	23.878	88.091	0.97843	13.739	66.061	79.800	24
26	40.056	25.360	87.870	1.0141	14.178	65.829	80.007	26
28	41.580	26.884	87.649	1.0507	14.618	65.596	80.214	28
30	43.148	28.452	87.426	1.0884	15.058	65.361	80.419	30
32	44.760	30.064	87.202	1.1271	12.500	65.124	80.624	32
34	46.417	31.721	86.977	1.1668	15.942	64.886	80.828	34
36	48.120	33.424	86.751	1.2077	16.384	64.647	81.031	36
38	49.870	35.174	86.524	1.2496	16.828	64.406	81.234	38
40	51.667	36.971	86.296	1.2927	17.273	64.163	81.436	40
42	53.513	38.817	86.066	1.3369	17.718	63.919	81.637	42
44	55.407	40.711	85.836	1.3823	18.164	63.673	81.837	44
46	57.352	42.656	85.604	1.4289	18.611	63.426	82.037	46
48	59.347	44.651	85.371	1.4768	19.059	63.177	82.236	48
50	61.394	46.698	85.136	1.5258	19.507	62.926	82.433	50
52	63.494	48.798	84.900	1.5762	19.957	62.673	82.630	52
54	65.646	50.950	84.663	1.0278	20.408	62.418	82.826	54
56	67.853	53.157	84.425	1.6808	20.859	62.162	83.021	56
58	70.115	55.419	84.485	1.7352	21.312	61.903	83.215	58
60	72.433	57.737	83.944	1.7909	21.766	61.643	83.409	60
62	74.807	60.111	83.701	1.8480	22.221	61.380	83.601	62
64	77.239	62.543	83.457	1.9066	22.676	61.116	83.792	64
66	79.729	57.033	83.212	1.9666	23.133	60.849	83.982	66
68	82.279	67.583	82.965	2.0282	23.591	60.580	84.171	68
70	84.888	70.192	82.717	2.0913	24.050	60.309	84.359	70
72	87.559	72.863	82.467	2.1559	24.511	60.035	84.546	72
74	90.292	75.596	82.215	2.2222	24.973	59.759	84.732	74
76	93.087	78.391	81.962	2.2901	25.435	59.481	84.916	76
78	95.946	81.250	81.707	2.3597	25.899	59.201	85.100	78

Table I. Properties of saturated refrigerant R-12-(con't).

Temp. °F.	Pressure		Density lb/cu ft		Heat content above —40°F. Btu/lb			Temp. °F.
	psia	psig	liquid	vapor	liquid	latent	total of vapor	
col. 1	col. 2	col. 3	col. 4	col. 5	col. 6	col. 7	col. 8	col. 9
80	98.870	84.174	81.450	2.4310	26.365	58.917	85.282	80
82	101.86	87.16	81.192	2.5041	26.832	58.631	85.463	82
84	104.92	90.22	80.932	2.5789	27.300	58.343	85.643	84
86	108.04	93.34	80.671	2.6556	27.769	58.052	85.821	86
88	111.23	96.53	80.407	2.7341	28.241	57.757	85.998	88
90	114.49	99.79	80.142	2.8146	28.713	57.461	86.174	90
92	117.82	103.12	79.874	2.8970	29.187	57.161	86.348	92
94	121.22	106.52	79.605	2.9815	29.663	56.858	86.521	94
96	124.70	110.00	79.334	3.0680	30.140	56.551	86.691	96
98	128.24	113.54	79.061	3.1566	30.619	56.242	86.861	98
100	131.86	117.16	78.785	3.2474	31.100	55.929	87.029	100
102	135.56	120.86	78.508	3.3404	31.583	55.613	87.196	102
104	139.33	124.63	78.228	3.4357	32.067	55.293	87.360	104
106	143.18	128.48	77.946	3.5333	32.553	54.970	87.523	106
108	147.11	132.41	77.662	3.6332	33.041	54.643	87.684	108
110	151.11	136.41	77.376	3.7357	33.531	54.313	87.844	110
112	155.19	140.49	77.087	3.8406	34.023	53.978	88.001	112
114	159.36	144.66	76.795	3.9482	34.517	53.639	88.156	114
116	163.61	148.91	76.501	4.0584	35.014	53.296	88.310	116
118	167.94	153.24	76.205	4.1713	35.512	52.949	88.461	118
120	172.35	157.65	75.906	4.2870	36.013	52.597	88.610	120
122	176.85	162.15	75.604	4.4056	36.516	52.241	88.757	122
124	181.43	166.73	75.299	4.5272	37.021	51.881	88.902	124
126	186.10	171.40	74.991	4.6518	37.529	51.515	89.044	126
128	190.86	176.16	74.680	4.7796	38.040	51.144	89.184	128
130	195.71	181.01	74.367	4.9107	38.553	50.768	89.321	130
132	200.64	185.94	74.050	5.0451	39.069	50.387	89.456	132
134	205.67	190.97	73.729	5.1829	39.588	50.000	89.588	134
136	210.79	196.09	73.406	5.3244	40.110	49.608	89.718	136
138	216.01	201.31	73.079	5.4695	40.634	49.210	89.844	138
140	221.32	206.62	72.748	5.6184	41.162	48.805	89.967	140

Table II. Properties of saturated refrigerant R-22.

Temp. °F.	Pressure		Density lb/cu ft		Heat content above —40°F. Btu/lb			Temp. °F.
	psia	psig	liquid	vapor	liquid	latent	total of vapor	
col. 1	col. 2	col. 3	col. 4	col. 5	col. 6	col. 7	col. 8	col. 9
—60	8.86	11.89**	90.03	0.1834	—5.16	103.24	98.09	—60
—58	9.39	10.81**	89.84	0.1936	—4.65	102.97	98.32	—58
—56	9.94	9.69**	89.65	0.2041	—4.13	102.69	98.56	—56
—54	10.51	8.53**	89.46	0.2151	—3.61	102.41	98.80	—54
—52	11.11	7.31**	89.27	0.2265	—3.09	102.13	99.04	—52
—50	11.74	6.03**	89.08	0.2386	—2.58	101.86	99.28	—50
—48	12.40	4.68**	88.88	0.2509	—2.06	101.58	99.52	—48
—46	13.09	3.28**	88.68	0.2636	—1.54	101.30	99.76	—46
—44	13.80	1.83**	88.49	0.2769	—1.02	101.02	100.00	—44
—42	14.54	0.326**	88.30	0.2907	—0.51	100.74	100.23	—42
—40	15.31	0.610	88.10	0.3050	0.00	100.46	100.46	—40
—38	16.12	1.42	87.90	0.3199	0.53	100.17	100.70	—38
—36	16.97	2.27	87.70	0.3355	1.05	99.88	100.93	—36
—34	17.85	3.15	87.50	0.3517	1.58	99.59	101.17	—34
—32	18.77	4.07	87.29	0.3686	2.10	99.30	101.40	—32
—30	19.72	5.02	87.09	0.3862	2.62	99.01	101.63	—30
—28	20.71	6.01	86.89	0.4043	3.15	98.71	101.86	—28
—26	21.73	7.03	86.69	0.4229	3.69	98.41	102.10	—26
—24	22.79	8.09	86.48	0.4421	4.22	98.11	102.33	—24
—22	23.88	9.18	86.27	0.4619	4.75	97.81	102.56	—22

Table II. Properties of saturated refrigerant R-22-(con't).

Temp. °F.	Pressure		Density lb/cu ft		Heat content above —40°F. Btu/lb			Temp. °F.
	psia	psig	liquid	vapor	liquid	latent	total of vapor	
col. 1	col. 2	col. 3	col. 4	col. 5	col. 6	col. 7	col. 8	col. 9
—20	25.01	10.31	86.06	0.4822	5.28	97.51	102.79	—20
—18	26.18	11.48	85.85	0.5032	5.82	97.20	103.02	—18
—16	27.39	12.69	85.64	0.5249	6.40	96.89	103.25	—16
—14	28.64	13.94	85.43	0.5474	6.90	96.58	103.48	—14
—12	29.94	15.24	85.21	0.5707	7.43	96.27	103.70	—12
—10	31.29	16.59	84.99	0.5948	7.96	95.96	103.92	—10
— 8	32.69	17.99	84.78	0.6198	8.49	95.65	104.14	— 8
— 6	34.14	19.44	84.56	0.6456	9.02	95.34	104.36	— 6
— 4	35.64	20.94	84.34	0.6728	9.55	95.03	104.58	— 4
— 2	37.19	22.49	84.12	0.6997	10.09	94.71	104.80	— 2
0	38.79	24.09	83.90	0.7282	10.63	94.39	105.02	0
2	40.43	25.73	83.68	0.7574	11.17	94.07	105.24	2
4	42.14	27.44	83.45	0.7877	11.70	93.75	105.45	4
5	43.02	28.33	83.34	0.8034	11.97	93.59	105.56	5
6	43.91	29.21	83.23	0.8191	12.23	93.43	105.66	6
8	45.74	31.04	83.01	0.8514	12.76	93.11	105.87	8
10	47.63	32.93	82.78	0.8847	13.29	92.79	106.08	10
12	49.58	34.88	82.55	0.9191	13.82	92.47	106.29	12
14	51.59	36.89	82.32	0.9545	14.36	92.14	106.50	14
16	53.66	38.96	82.09	0.9911	14.90	91.81	106.71	16
18	55.79	41.09	81.86	1.029	15.44	91.48	106.92	18
20	57.98	43.28	81.63	1.067	15.98	91.15	107.13	20
22	60.23	45.53	81.39	1.107	16.52	90.81	107.33	22
24	62.55	47.85	81.16	1.149	17.06	90.47	107.53	24
26	64.94	50.24	80.92	1.191	17.61	90.12	107.73	26
28	67.40	52.70	80.69	1.235	18.17	89.76	107.93	28
30	69.93	55.23	80.45	1.280	18.74	89.39	108.13	30
32	72.53	57.83	80.21	1.326	19.32	89.01	108.33	32
34	75.21	60.51	79.97	1.373	19.90	88.62	108.52	34
36	77.97	63.27	79.73	1.422	20.49	88.22	108.71	36
38	80.81	66.11	79.49	1.473	21.09	87.81	108.90	38
40	83.72	69.02	79.25	1.525	21.70	87.39	109.09	40
42	86.69	71.99	79.00	1.578	22.29	86.98	109.27	42
44	89.74	75.04	78.76	1.632	22.90	86.55	109.45	44
46	92.88	78.18	78.51	1.689	23.50	86.13	109.63	46
48	96.10	81.40	78.26	1.747	24.11	85.69	109.80	48
50	99.40	84.70	78.02	1.806	24.73	85.25	109.98	50
52	102.8	88.10	77.77	1.868	25.34	84.80	110.14	52
54	106.2	91.5	77.51	1.929	25.95	84.35	110.30	54
56	109.8	95.1	77.26	1.995	26.58	83.89	110.47	56
58	113.5	98.8	77.01	2.062	27.22	83.41	110.63	58
60	117.2	102.5	76.75	2.130	27.83	82.95	110.78	60
62	121.0	106.3	76.50	2.200	28.46	82.47	110.93	62
64	124.9	110.2	76.24	2.271	29.09	81.99	111.08	64
66	128.9	114.2	75.98	2.346	29.72	81.50	111.22	66
68	133.0	118.3	75.72	2.422	30.35	81.00	111.35	68
70	137.2	122.5	75.46	2.500	30.99	80.50	111.49	70
72	141.5	126.8	75.20	2.581	31.65	79.98	111.63	72
74	145.9	131.2	74.94	2.664	32.29	79.46	111.75	74
76	150.4	135.7	74.68	2.749	32.94	78.94	111.88	76
78	155.0	140.3	74.41	2.836	33.61	78.40	112.01	78
80	159.7	145.0	74.15	2.926	34.27	77.86	112.13	80
82	164.5	149.8	73.89	3.019	34.92	77.32	112.24	82
84	169.4	154.7	73.63	3.112	35.60	76.76	112.36	84
86	174.5	159.8	73.36	3.213	36.28	76.19	112.47	86
88	179.6	164.9	73.09	3.313	36.94	75.63	112.57	88
90	184.8	170.1	72.81	3.415	37.61	75.06	112.67	90
92	190.1	175.4	72.53	3.520	38.28	74.48	112.76	92
94	195.6	180.9	72.24	3.630	38.97	73.88	112.85	94
96	201.2	186.5	71.95	3.742	39.65	73.28	112.93	96
98	206.8	192.1	71.65	3.855	40.32	72.68	113.00	98
100	212.6	197.9	71.35	3.973	40.98	72.08	113.06	100
102	218.5	203.8	71.05	4.094	41.65	71.47	113.12	102
104	224.6	209.9	70.74	4.220	42.32	70.84	113.16	104
106	230.7	216.0	70.42	4.347	42.98	70.22	113.20	106
108	237.0	222.3	70.11	4.479	43.66	69.58	113.24	108

Assume that the design of a particular item of equipment calls for the refrigerant (R-12 in this case) to boil at 40° F. Referring to table I, it is found that the pressure in the evaporator (where the refrigerant vaporizes and absorbs heat) at that temperature will be 36.971 psig. For practical purposes, it can be assumed that pressure at the inlet (suction side) of the compressor will also be 36.971 psig. Pressure of the vapor must now be raised to allow the condensing medium at a normal temperature to remove heat that was picked up by the R-12 refrigerant as it passed through the evaporator. If the condensing medium being circulated around the refrigerant tubes (condenser) was of the same temperature as the refrigerant, no heat exchange would occur. Making the additional assumption that the refrigerant must be condensed on the high-side of the system, at 110° F to enable the medium to condense it effectively, you will find it by referring to table I and further you will find that the condensing pressure will be 136.41 psig.

A further study of Tables I and II will show a wide range of additional information that can be derived from the refrigerant tables, such as refrigerant effect, system requirements, compressor size, and whether a system is operating at the efficiency for which it was designed.

● REFRIGERATING EFFECT - If a specific job is to be done in a refrigeration system or cycle, each pound of refrigerant circulating in the system must do its share of the work. It must absorb an amount of heat in the evaporator or cooling coil, and it must dissipate this heat (plus some heat that is added in the compressor) out through the condenser, whether air-cooled, water-cooled, or evaporatively cooled. The work done by each pound of refrigerant as it goes through the evaporator is reflected by the amount of heat it picks up from the refrigeration load, chiefly when the refrigerant undergoes a change of state from a liquid to a vapor.

When the refrigerant, as a liquid, leaves the condenser, may go to a receiver until it is required in the evaporator, or it may go directly into the liquid line to the metering device and then into the evaporator coil. The liquid entering the metering device just ahead of the evaporator coil will have a certain heat content which is dependent on its temperature when it enters the coil, as it is shown in the refrigerant tables. The vapor leaving the evaporator will also have a given heat content according to its temperature. This too is shown in the refrigerant tables.

The difference between these two amounts of heat content is the amount of work done by each pound (lb) of refrigerant as it passes through the evaporator and picks up heat. The amount of heat absorbed by each pound of refrigerant is known as the REFRIGERATION EFFECT of the system or within the system.

This refrigeration effect is rated in Btu per pound of refrigerant (Btu/lb). Although there are numerous formulas for computing refrigeration effect, you will use the tables to calculate two ways in which refrigeration effect or work being done by each pound of refrigerant under certain conditions is determined.

For example, assume that R-12 in the coils has a temperature of 40° F, and the temperature of the liquid just before the expansion valve (metering device) is 100° F. From table I, column 8, the heat content of the vapor at 40° F is 81.436 Btu/lb; the heat content of the liquid at 100° F, column 6, is 31.1 Btu/lb. Therefore, the refrigeration effect will be 81.436 Btu/lb minus 31.1 Btu/lb, or 50.335 Btu/lb. In other word, one pound of R-12 will absorb 50.335 Btu's per pound of refrigerant in passing through the refrigeration system under the preceding conditions.

As a second example, using the table of saturated R-12 (Table I), it can be seen that the heat content of 100° F liquid is 31.10 Btu/lb (column 6) and that 40° F liquid is 17.27 Btu/lb (column 6). This indicates that 13.83 Btu/lb (31.10 Btu/lb minus 17.27 Btu/lb has to be removed from each pound of refrigerant entering the evaporator. The latent heat of vaporization of 40° F R-12 is 64.17 Btu/lb (column 7), and the difference between this amount and that which is given up by each pound of refrigerant when its liquid temperature is lowered from 100° to 40° F is 50.34 Btu/lb. (Note: This 50.34 Btu/lb is for a particular evaporator and refrigerant and is NOT the same in all cases.)

As another example let's use a different refrigerant. From the table of saturated R-22 (Table II), it can be seen that the heat content of 100° F liquid is 40.98 Btu/lb, this figure is obtained from column 6, and that 40° F liquid is 21.70 Btu/lb, this figure also was obtained from column 6. This would indicate that 19.28 Btu/lb (40.98 Btu/lb subtracted by 21.70 Btu/lb) has to be removed from each pound of refrigerant entering the evaporator. The latent heat of vaporization of 40° F R-22 is 87.39 Btu/lb, (this quantity was obtained from column 7), and the difference between this amount and that which is given up by each pound of refrigerant, when its liquid temperature is lowered from 100° F to 40° F, is 68.11 Btu/lb (87.39 Btu/lb minus 19.28 Btu/lb).

Again, it must be emphasized that the refrigeration effect will be different depending on the particular evaporator and refrigerant used in the system. This can be seen by the examples that have been or will be given. An example of this is as follows: If we were to use R-12 as the refrigerant in the system, increase the temperature of the refrigerant liquid from the condenser to 110° F and decrease the temperature of the liquid refrigerant to 30° F. Using the table of saturated R-12, you see that the heat content of 110° F liquid is 33.53 Btu/lb and that of 30° F liquid is 15.05 Btu/lb. From this, you will find that 22.47 Btu/lb has to be removed from each pound of refrigerant entering the evaporator. (Remember, because of the small orifice in the metering device, when the compressed refrigerant passes from the smaller opening in the metering device to the larger tubing in the evaporator, a change in pressure occurs along with a change in temperature.) The latent heat of vaporization of 30° F R-12 is 65.36 Btu/lb, and the difference between this amount and that which is given up by each pound of refrigerant when its liquid temperature is lowered from 110° F to 30° F is 42.89 Btu/lb. This quantity is obtained by subtracting from 65.36 Btu/lb (column 7) 22.47 Btu/lb (the amount of heat that must be removed from each pound of refrigerant entering the evaporator).

● SYSTEM REQUIREMENTS - In order to obtain the desired cooling level (system requirement), you must be able to determine the proper amount of refrigerant required in a particular system. To find this, first determine the amount of heat per hour to be removed in Btu's (this would be predetermined by heat calculations). Divide this (the amount of heat per hour to be removed) by the heat removal potential (refrigeration effect) per pound of refrigerant and if the total heat load is known, given in Btu's per hour, you can find the total number of pounds of refrigerant that must be circulated during each hour of operation of the system to obtain the desired cooling level. This figure can be further broken down to the amount that must be circulated each minute by dividing the amount circulated per hour by 60.

Example:

If the total heat load to be removed is 60,000 Btu's per hour, and the refrigerating effect in the evaporator amounts to 50 Btu/lb, then:

$$\frac{\text{60,000 Btu's per hour}}{\text{50 Btu's per pound}} = \text{1,200 pounds per hour or 20 pounds per minute.}$$

Since 12,000 Btu's per hour equals the rate of one ton of refrigeration, the 60,000 Btu/hr in the above example amounts to 5 ton of refrigeration,

$$\frac{\text{60,000 Btu/hr}}{\text{12,000 Btu/hr}} = \text{5 tons of refrigeration}$$

and the 20 lbs of refrigerant that must be circulated each minute is equivalent of 4 lbs per minute per ton of refrigeration. You know that one ton of refrigeration for 24 hours is equal to 288,000 Btu's.

In this example, where 20 lbs of refrigerant having a refrigerating effect of 50 Btu/lb is required to take care of the specified load of 60,000 Btu/hr, the result can also be obtained in another manner. As previously mentioned, it takes 12,000 Btu/hr to equal 1 ton of refrigeration, which is equal to 200 Btu/min/ton.

$$\frac{\text{12,000 Btu}}{\text{60 min}} = \text{200 Btu/min/ton}$$

Therefore, 200 Btu/min/ton when divided by the refrigerating effect of 50 Btu/lb amounts to 4 lbs/min/ton.

$$\frac{\text{200 Btu/min/ton}}{\text{50 Btu/lb}} = \text{4 lbs/min/ton}$$

To obtain the amount of refrigerant required for the 60,000 Btu/hr, multiply 4 lbs/min/ton by 5 tons of refrigeration, which will equal 20 lbs/hr.

To find the amount of R-22 required in a system which has a heat load of 36,000 Btu/hr and a refrigerating effect in the evaporator amounts to 68 Btu/lb.

$$\frac{\text{36,000 Btu/hr}}{\text{68 Btu/lb}} = \text{529.4 lbs/hr or 8.82 lbs/min}$$

From this example, you can see that it will take 8.82 pounds of refrigerant per minute of R-22 circulating in the system to obtain the desired cooling level of 36,000 Btu/hr.

- COMPRESSOR SIZE - The required displacement, in cubic feet per minute, of the compressor for a system may be determined by reducing the hourly supply of refrigerant required to a per minute basis and dividing the quantity by the density of the refrigerant vapor leaving the evaporator. Because the compressor is not 100% efficient, the calculated displacement must be divided by the volumetric efficiency, expressed as a decimal, to determine the actual compressor displacement required.

The capacity of the compressor must be such that it will remove from the evaporator that amount of refrigerant which has vaporized in the evaporator and the metering device in order to get the necessary work done. The compressor must be able to remove and send on to the condenser the same weight of refrigerant vapor, so that it can be condensed back into a liquid and so continue in the refrigeration cycle to perform additional work.

If the compressor, because of design or speed, is unable to move this weight, some of the vapor will remain in the evaporator. This, in turn, will cause an increase in pressure inside of the evaporator, accompanied by an increase in temperature and a decrease in the work being done by the refrigerant, as a result the design conditions within the refrigerated space cannot be maintained. A compressor that is too large will withdraw the refrigerant from the evaporator too rapidly, causing a lowering of the temperature inside of the evaporator, so the design conditions will not be maintained in this situation either.

As you can see, refrigerant tables provide many methods of checking and cross checking temperature and pressure readings, plus numerous other bits of information that you will need to know. It is not your function as a refrigeration technician to determine the proper size and performance characteristics of a refrigeration system. However, you should be able to determine whether a system is operating at the efficiency for which it was designed. By using the refrigerant tables you should be able to accomplish your mission.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

Note: Questions 1 through 3 refer to the refrigerant table for R-12.

1. In a refrigeration system designed for R-12 to boil at 36° F and condense at 104° F, what would the condensing pressure be?

   ____

2. For the conditions described in question #1, what would the evaporator pressure be?

   ____

3. For the conditions described in question #1, what is the refrigerating effect?

   ____

Note Questions 4 through 6 refer to the refrigerant table for R-22.

4. What is the density of R-22 vapor at -28° F?

   ____

5. What is the total heat content of R-22 vapor at 32° F?

   ____

6. What is the absolute pressure of R-22 at a temperature of 56° F?

   ____

7. Assume you have a refrigeration system designed to use R-22, rated at 60,000 BTU/hr and the evaporator temperature is 40° F, and the condensing temperature is 100° F. Determine the quantity of refrigerant in pounds per hour required to circulate in the system to obtain the desired cooling level.

   ____

Work Unit 2-4. STORAGE AND HANDLING OF COMPRESSED GASES

SPECIFY IN WRITING TWO IMPORTANT REASONS FOR PROPER IDENTIFICATION OF COMPRESSED GAS CYLINDERS.

STATE TWO ITEMS OF INFORMATION FOUND ON COMPRESSED GAS CYLINDER DECALS.

IN REFILLING, SPECIFY THE MAXIMUM QUANTITY OF REFRIGERANT THAT IS PLACED IN A EMPTY CYLINDER.

SPECIFY IN WRITING THE PROTECTION ACCORDED REFRIGERANT CYLINDERS DURING THE WINTER.

SPECIFY IN WRITING THE PROTECTION ACCORDED REFRIGERANT CYLINDERS DURING THE SUMMER.

As a refrigeration technician, you must be able to tell the difference between the numerous compressed gases that you may come into contact with during the performance of your duties. The way in which you will be able to do this is to identify the different markings of the cylinders that contain compressed gas. You must also know the correct procedures for handling and storing these cylinders. In the performance of your duties, you will be actively involved in transferring and measuring refrigerant.

In the following work unit, the identification, handling, storage of compressed gases and the cylinders that they are in, plus transferring and measuring refrigerants will be discussed.

You will find there are many types of gases used throughout the Marine Corps. Although, while performing your duties you will come into contact with only a few on a day to day basis, you should be capable of identifying all cylinders that you may encounter as a refrigeration technician.

The most important reasons for identifying compressed gases properly is to first PREVENT PERSONAL INJURY and secondly PREVENT PROPERTY DAMAGE that may result if compressed gases are not handled properly. In the past, many incidents of property damage and personal injury have occured because one gas cylinder was mistaken for another. To prevent this, rigid color codes have been established to make it PRACTICALLY impossible to confuse gas cylinders.

Gases have been broken down into nine classes, and each has its own color. The following are the classes of gases and their assigned color code:

GAS	BASIC COLOR OF CYLINDERS
Industrial	Tan
Medical	Blue
Toxic material	Brown
Refrigerant	Orange
Fuel	Red
Inert	Gray
Oxidizing	Black
Oxygen	Green

Fig 2-9. Types of gases and colors of cylinders.

Figure 2-9 shows some of the more common gases that you, as a refrigeration technician, will come in contact with, their color markings, usage, and safety precautions for handling them.

Gases (Asterisk indicates high-pressure gas)

GAS	CONTAINER SIZE	COLOR MARKINGS	USE	PRECAUTIONS
*Compressed gas	200 ft^3 cyl	Black w/green stripe	General	General safe handling. Air under pressure is dangerous
*Carbon dioxide	15 lb cyl	Gray	Recharging fire extinguishers, soda fountains, etc.	General safe handling

Gases (Asterisk indicates high-pressure gas)

GAS	CONTAINER SIZE	COLOR MARKINGS	USE	PRECAUTIONS
*Carbon dioxide	Various weights	Red	Fire extinguishers	General safe handling
*Oxygen	200 ft^3 cyl 100 ft^3 cyl 55 ft^3 cyl	Green	General welding and cutting purposes.	Dangerous fire hazard. Do not store near combustible gases or flammable materials.
	200 ft^3 cyl	Green w/white stripe	Refilling small aviator's breathing cyls.	NEVER LUBRICATE
*Acetylene	10 ft^3 cyl 40 ft^3 cyl 225 ft^3 cyl	Yellow	Welding, cutting and heating procedures	Highly flammable. Store cyl. upright. Keep valves closed
*Chlorine	30 ft^3 cyl 100 ft^3 cyl 120 ft^3 cyl 150 ft^3 cyl	Brown	For chlorinating water supply systems	POISON Store cyl upright
Refrigerant R-12	10 lb cyl 35 lb cyl 100 lb cyl	Orange	Refrigerating systems	General safe handling
Refrigerant R-22	10 lb cyl 35 lb cyl 100 lb cyl	Orange	Refrigerating systems	General safe handling
Refrigerant R-11	Bulk	Orange	Refrigerating systems	General safe handling
Refrigerant R-502	35 lb cyl	Orange	Refrigerating systems	General safe handling
Ethyl chloride	50 lb cyl	Orange w/ yellow stripe	Refrigerating systems	Highly flammable
Ammonia	50 lb cyl	Orange w/ brown cap and yellow stripe	Refrigerating systems	Guard against leaks. Isolate from others. If conventional base, store upright in cool place.

Fig 2-9. Compressed gas cylinders, their markings, and safety precautions.

Other identifying features consist of the name of the gas stenciled lengthwise on the cylinder in 2 inch letters in two places, and two oval decals 3-1/2 inch long by 1-1/2 inch wide. These decals show the name of the gas, proper handling precautions, and the amount of pressure to be left in the cylinder when it is returned for refilling. The decals are of the same background color as the identification color of the gas.

Most refrigerants are shipped and stored in compressed gas cylinders of some type, which are made of high quality steel and conform to ICC (Interstate Commerce Commission) specifications. These regulations pertaining to the manufacture cover testing, filling, and shipment of all compressed gas containers and are subject to interstate transportation laws.

There are three types of refrigerant cylinders: storage, returnable, and disposable. Safety regulation prescribed by ICC regulations require that cylinders which have contained a corrosive refrigerant must be checked every five years. Cylinders containing noncorrosive refrigerants must be checked every 10 years. All cylinders over 4-1/2 inch in diameter and 12 inches long must contain some type of pressure release protective device, a fusible plug, or a spring operated relief valve.

- HANDLING CYLINDERS - Refrigerant cylinders should be considered full and handled with care at all times to prevent possible accidents. They must NEVER be dropped or allowed to forcefully strike each other or any other object. When cylinders are standing upright, they should be fastened to prevent them from being upset accidentally. Particular care should be taken by personnel NOT to strike the cylinder valve when a valve protection cap is not in place on the cylinder. Suitable trucks with provisions for holding cylinders securely in position are to be used for conveying and handling cylinders. Cylinders must NOT be lifted by cranes or by mechanical lifts unless they are fastened in special containers, racks, or cradles. Rope or chain slings are NOT to be used. Cylinders should NEVER be lifted by grasping the valve or valve protection cap.

- CYLINDER STORAGE - Refrigeration cylinders must be protected against excessive rise and/or fall of temperature. If possible, cylinders should be stored indoors in a cool, dry place. Storage areas must be well ventilated to prevent the possible accumulation of explosive or harmful concentrations of gas. Cylinders stored in the open must be protected from ice and snow in the winter. In the summer, they must be protected or screened from the direct rays of the sun. Ventilation should be provided to keep temperatures below 125° F and to carry off any possible leakage. Refrigerant cylinders must not be stored near highly flammable materials such as oil, gasoline, and waste, or in a location where heavy objects may fall on or strike them. Smoking should be PROHIBITED wherever cylinders are stored. Steps must be taken to insure that cylinders do not get knocked over. Empty cylinders must be kept separate from full ones.

Now that the procedures for handling and storing refrigerant cylinders have been discussed, you will learn how to transfer and measure refrigerants that were mentioned earlier. Figure 2-10 will show you the common refrigerant cylinders that you will undoubtedly encounter.

Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. The liquid refrigerants are usually removed from their shipping containers (fig 2-10, #6) and transferred to a service cylinder (fig 2-10, #3 thru #5) or to a refrigeration unit if the quantity of refrigerant calls for a large quantity. When small quantities of gaseous refrigerants are desired, they may be removed directly from the upright cylinder. However, since vaporization of the refrigerant requires heat, the cylinder must be heated from some external source other than room temperature, unless only small quantities are required. Cylinders may be heated by immersing them in hot water or by wrapping them in a hot towel at less than 120° F. Heating by FLAME is NOT recommended because of the possibility of a fire or explosion.

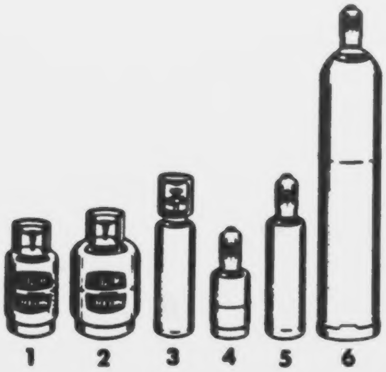


Fig 2-10. Refrigerant cylinders.

As a refrigeration technician, you will usually carry a small service cylinder that weighs 4 to 30 lbs, which you will use when charging refrigeration systems. The service cylinders are usually filled from the storage cylinders located in the shop.

When a service cylinder is to be filled, it should be placed on a scale to determine its weight. Refrigerant service cylinders must NEVER be overfilled because a rupture, due to extreme pressure, may result, and this endangers the lives of personnel in the area. A platform scale, such as the one shown in figure 2-11, is usually used. After the drum (service cylinder) is initially weighed, it should be chilled by placing it in ice water or a refrigerated tank. It is then connected to the supply cylinder with a charging line and again placed on the scales. At this time the air should be purged from the charging line (hose) by opening the supply cylinder valve for an instant with the flare nut loose on the service cylinder, refer to figure 2-11. After purging the charging hose, tighten the flare nut and open the valve on the service cylinder. Now, open the valve on the supply cylinder to permit the refrigerant to flow into the service cylinder. When the weight of the cylinder indicates that the proper amount of refrigerant has been transferred, close all valves tightly. Disconnect the charging hose at the service cylinder and cap all openings. The filled weigh of a refrigerant cylinder must not exceed its empty weight plus the rated refrigerant capacity for a cylinder of that particular size.

NEVER completely fill a refrigerant cylinder with a liquid refrigerant. Always allow space for the refrigerant to expand. Liquid refrigerant expands with an increase in temperature, as you should always know. A cylinder completely filled with cold or cool refrigerant will burst if allowed to warm. To check, shake the cylinder end to end. If there is unfilled space, the liquid refrigerant will be able to be heard as it sloshes from end to end; a completely filled cylinder will make no sound. The SAFE LIMIT for a cylinder is 85% filled.

Some shops will not have the capability to refill service cylinders. Returnable service cylinders are exchanged at supply issue point. Empty cylinders are returned and full ones are provided as a replacement on a one for one basis.

The use of returnable service cylinders is being reduced because of the increase in the use of DISPOSABLE service cylinders. Refer to figure 2-12 for examples of disposable service cylinders.

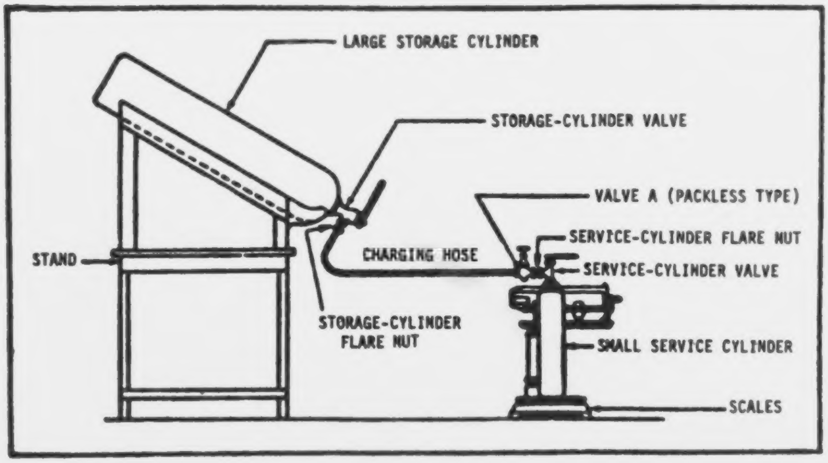


Fig 2-11. Transferring refrigerants.

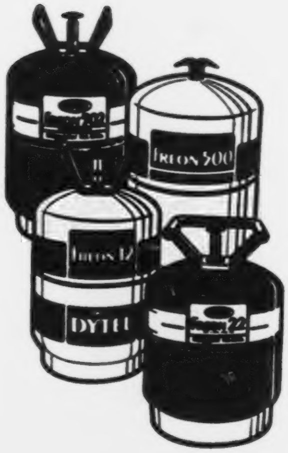


Fig 2-12. Disposable service cylinders.

Many popular refrigerants are now available in small quantities from a few ounces to 30 lbs in disposable (throwaway) cylinders. These containers are easy to handle and they eliminate the problem of refilling. Figure 2-12 illustrates popular throwaway cylinders.

Most disposable cylinders are fitted with relief valves. These are usually located in the valve body. Some throwaway refrigerant containers are sealed cans. The top is made in such a way that a special service valve can be tightly clamped to the top of the can. This valve, when clamped on the can, can be made to puncture it, thus providing a means of drawing the refrigerant from the container.

Disposable cylinders MUST NEVER be recharged nor used to store those refrigerants that are removed from a system that is undergoing repairs.

With the advent of disposable cylinders, all cylinders are color coded to permit easy identification. The following is a list of the color codes currently in use:

REFRIEGERNAT	CYLINDER COLOR CODE
R-11	Orange
R-12	White
R-22	Green
R-502	Orchid

NEVER rely totally on the color code on any cylinder or container to identify compressed gases; be sure to read the label. If you have any questions, do not use the gas in the cylinder until your questions have been answered and the contents of that container is verified.

The following is a list of 13 rules that you should follow when working with refrigerant cylinders:

- NEVER drop the cylinder or permit them to strike each other.
- NEVER use a lifting magnet or a sling when handling cylinders. A crane may be used only if a cradle or safe platform is provided.
- Keep cylinder valve caps on at all times, except when the cylinder is being used.

- NEVER completely fill a cylinder; 85% is the maximum safe limit. Overfilled cylinders are apt to burst due to the hydrostatic pressure.
- NEVER mix refrigerants in a cylinder.
- NEVER use cylinders for a support or roller.
- NEVER tamper with the safety device on a cylinder.
- Open cylinder valves very slowly and use a cylinder valve wrench. DO NOT use a pipe or monkey wrench.
- NEVER force misfitting connections. Make sure all connections are of the same size as those on the cylinder.
- NEVER attempt to repair or alter a cylinder or its valve.
- NEVER store cylinders near flammable or combustible materials.
- Always keep cylinders in a cool place and away from direct rays of the sun.
- NEVER store full and empty cylinders in the same location.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The reason for proper identification of compressed gases is to prevent____________________ and ____________________.

2 Besides showing the amount of pressure to be left in the cylinder when it is returned for refilling, what are two other items of information found on the decals affixed to the cylinders?

a. ____

b ____

3. What means is used to determine the quantity of refrigerant in a cylinder?

____

4. When refilling a cylinder, what is the maximum percentage of a refrigerant that can be safely placed in the cylinder?

____

5. In the winter, cylinders stored in the open must be protected from ____________________and ____________________.

6. In the summer, cylinders must be protected or screened from ____________________.

7. Ventilation should be provided to keep temperatures below ____________ when refrigerants are stored during the summer.

Work Unit 2-5. LUBRICANTS

STATE AN IMPORTANT ASPECT OF LUBRICATION IN THE MAINTENANCE OF THE MECHANICAL COMPONENTS OF A REFRIGERATION SYSTEM.

DEFINE THE VISCOSITY OF A LUBRICATING OIL.

LIST THE TWO PRINCIPAL METHODS OF PROPER COMPRESSOR LUBRICATION.

STATE THE PURPOSE OF AN OIL SEPARATOR IN A REFRIGERATION SYSTEM.

LIST THE THREE MAIN CATEGORIES OF REFRIGERANT OILS.

In refrigeration systems the moving parts in several of the components create friction, which can be destructive to metal surfaces. In addition, this friction results in an increase in the temperature of the moving parts involved. Because proper lubrication reduces possible damage resulting from friction, it is an important aspect in the maintenance of the mechanical refrigeration system's components. The compressor requires PROPER LUBRICATION for its bearings, pistons, and gears.

In the case of a reciprocating compressor, the space between the piston and cylinder wall must be sealed off so that all refrigerant vapor will be forced out of the cylinder and into the hot gas discharge line. This sealing off is accomplished by the refrigerant oil as it is forced to travel along with the compressed refrigerant vapor. If the oil film does not seal off the space as the piston moves back and forth in the compressor crankcase, a loss in efficiency will result.

As mentioned earlier, oil used in refrigerating systems mixes with and travels along with most refrigerants in the liquid state. It is imperative that oil from the crankcase be forced out of the compressor and into the condenser through the hot gas line. In order to maintain proper lubrication of the moving parts and to keep the correct oil level in the compressor crankcase, the oil must complete the circuit along with the refrigerant, and then it must make its way back to the compressor.

Traveling with the liquid refrigerant, the oil will reach the evaporator, which is one of the components in which moving the oil presents a problem. If the oil does not travel from the evaporator to the suction line, the evaporator can become oil logged, decreasing the heat transfer surface of the cooling coil.

Suction lines must be sized correctly to maintain the velocity of the vapor, in order to entrain the oil with it through the circuit back to the crankcase of the compressor. If the oil is not returned to the compressor, this component could soon be operating in a "dry" condition. When this happens, no oil is pumped through the cylinder; therefore, the vapor seal will be gone, and the compressor will lose efficiency. If this situation continues uncorrected for a lengthly period, there will be damage to the compressor.

To principal methods are used for proper lubrication of compressors:

- The splash system
- The force-feed or pressure system

In the first method, lubrication is initiated by the revolving of the crankshaft in the oil within the crankcase. Fingers or throws on the crankshaft dip into the oil and throw it onto the bearings or small grooves that lead to the bearings and seal. Oil also is thrown onto the pistons and cylinder walls, thus maintaining the vapor seal between these components. The importance of keeping the proper oil level in the crankcase cannot be stressed too strongly, along with the need for keeping the oil moving through the system along with the refrigerant.

A small pump is used in the pressure system to force the oil to the bearings, seal, piston pins, pistons, and cylinder walls. A compressor, with this type of lubrication system, is, of course, more costly than one using the splash system; however, the former supplies more protection and assurance of proper lubrication of the compressor, as long as there is an adequate supply of oil in the crankcase.

Some compressors are inherent "oil pumpers." That is, they pump oil out along with the refrigerant vapor at a rate faster than it can be returned through the system to the crankcase. Often, the manufacturer will include an oil separator on the condensing unit. If the compressor is to be used in a built-up system, the manufacturer will recommend that such an oil separator be included in the installation.

Figure 2-13 shows a cutaway of an oil separator installed in a refrigeration circuit. It is important that the oil be returned to the compressor as soon as possible, so the oil separator is located between the compressor and the condenser. The high-temperature, high-pressure vapor, along with the oil forced out of the compressor travels through the discharge line from the compressor until it reaches the oil separator. There, its direction of flow is changed, and its rate of flow lessens, since the separator has a larger volume and cross-sectional area than does the discharge line. Depending upon the design of the separator, it may contain screens or other devices that will force the oil to drop into the reservoir of the separator, while the refrigerant vapor continues on its path through the separator.

Note: The oil separator must be insulated to prevent flash gas from occuring inside the separator.

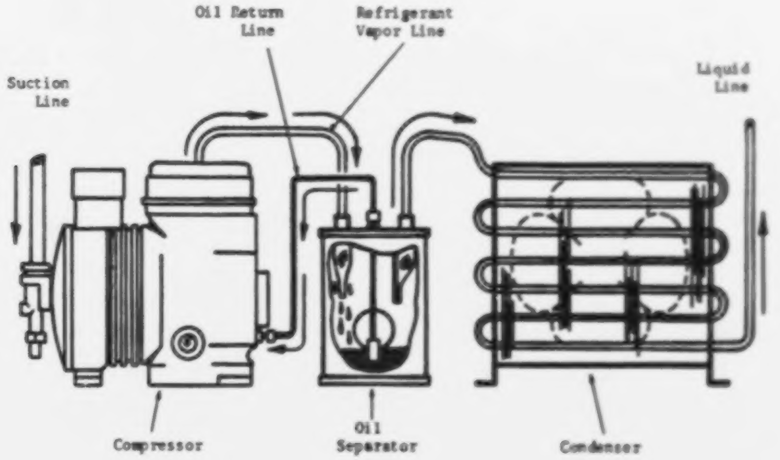


Fig 2-13. Oil separator.

As shown in figure 2-13, most separators contain float and valve assemblies for releasing the oil back into the compressor. When a given amount of oil has accumulated in the reservoir chamber of the separator, the buoyancy of the oil will raise the float and open the valve. The pressure of the refrigerant discharge vapor is greater than the pressure in the compressor crankcase, and this difference in pressure forces the oil to return to the crankcase. As the oil level in the separator lowers, so does the float, causing the needle valve to close and permitting the accumulation of more oil in the separator.

As was mentioned earlier, a refrigerant oil must have good lubricating qualities and the capability to seal off the low side from the high side in the compressor. While the oil lubricates the bearings in the compressor, it also acts as a cooling medium by removing from these bearings the heat caused by the friction of the moving components when the compressor is in operation.

The perfect oil to use with all refrigerants and under all conditions has not been developed as yet. Each of the refrigerant oils available has its good and not-so-good characteristics, and these must be balanced against the requirements of the installation and the use to which the particular system is to be put.

The following is a list of several qualities that a refrigerant oil must possess to be used within a refrigeration system:

- It must remain fluid at low temperatures.
- It must remain stable at high temperatures.
- It must not react chemically with the refrigerant, metals, motor insulation (when used in hermetic compressors), air, or other contaminates.
- It must not decompose into carbon under any anticipated operating conditions.

- It must not deposit wax when subjected to the low operating temperatures that must be met.
- It must be dry and as free of moisture as possible.

For all practical purposes, oils available for refrigeration systems are of mineral origin. They can be classified into three main categories: a PARAFFIN base oil, a NAPHTHENE base oil, and a mixture of paraffin and naphthene commonly referred to as a MIXED base oil. These different categories are derived from the crude oil found in different parts of the world. Proper refining processes remove the heavier paraffins and naphthenes from the crude oil.

The following is a list of characteristics that must be considered when determining a refrigerant oil to use; however, they are not listed in order of importance.

- Viscosity
- Pour point
- Floc point
- Flash point
- Dielectric strength
- Fire point
- Oxidation resistance
- Color

The VISCOSITY of a refrigerant oil, or any other liquid, is a measurement of its resistance to flow, or simply how thin or thick it is under a given set of conditions. A measured sample of the liquid, at a specific temperature, flows through a calibrated orifice. The time it takes, in seconds, expresses its viscosity.

The POUR POINT of an oil is the lowest temperature at which the oil will flow. Usually the temperature of the oil will be lowered to the point where it will no longer flow, and then 5° F is added to this temperature. (A low pour point is an indication that the oil will not congeal at the lowest temperature reached in the system at its designed operating conditions.)

It has been found that all refrigerant oils contain wax in varying degrees. This wax will separate from the other components in the oil when the temperature of the oil is lowered enough. When a refrigerant oil is dewaxed as much as possible (for the wax cannot be completely removed) tests are run to find the temperature at which the remainder of the wax separates from the oil.

When wax separates from the oil, the mixture of oil and refrigerant becomes cloudy. As the temperature of the mixture is lowered further, fine suspended particles of wax will form into small balls or clusters. The temperature at which this formation is visible is called the FLOC POINT of the oil.

Since wax will collect at the colder areas within the refrigeration system (the expansion valve and the evaporator), there will be a loss of heat transfer efficiency in the evaporator, and the expansion valve or other type of metering device may easily become restricted or clogged.

A particular oil may be used in high-temperature refrigeration or comfort air conditioning, but it may not be satisfactory for use in low-temperature applications. Therefore, the floc point is an important property to consider when choosing a refrigerant oil for a specific use.

Although refrigerant oils usually present no danger or fire hazard within various systems, it is important to know the FLASH POINT of a particular oil. This is the temperature at which oil vapor, when exposed to a flame, will flash into fire. This occurs at a specific temperature at which the oil becomes unstable and some of its components tend to separate. Therefore, the flash point of refrigerant oils must be avoided.

Many compressors and motors are hermetically sealed together in housing or shells, and the refrigerant vapor from the evaporator passes across the insulated motor windings. In such cases, the refrigerant oil must have a resistance to the flow of electric current, and it is the measurement of this resistance which is the DIELECTRIC STRENGTH of a refrigeration lubricating oil.

The FIRE POINT of a refrigerant oil is associated with the flash point of a fluid, which was previously described. When the temperature is increased beyond the flash point of the oil vapor and the oil continues to burn during the test, the oil's fire point has been reached.

Sulphur compounds in a refrigerant lubricating oil are undesirable. Sulphurous acid forms when moisture mixes with a sulphur compound. This acid, which is not considered much of a factor in oils today, can be very corrosive to the metal components of a refrigeration system. A good lubricating oil should show a minimun of CORROSIVE TENDENCY when a strip of highly polished copper is immersed in a sample of oil and subjected to temperature above 200° F. After a period of about three or four hours, the copper strip is removed from the oil sample. If it is pitted or more than slightly discolored, this is evidence that the oil contains too much sulphur.

STABILITY of the refrigerant lubricating oil was discussed in connection with the flash point of refrigerant oils. Still another indication of an oil's stability is its resistance to chemical reaction, OXIDATION RESISTANCE.

Oil to be used in most lubricating processes must be refined to remove unsaturated hydrocarbons, but the more an oil is refined the lower its lubricating quality. In the early days of refrigeration, oil used in this process was continuously refined until it was almost colorless. The COLOR of a good refrigerant oil ordinarily is light yellow; this indicates that most of the hydrocarbons have been refined without having lost their lubricating qualities.

Refrigerant oils must be kept in sealed, chemically clean containers. Any lines or containers used to transfer these oils must also be chemically clean. Refrigerant oil left exposed to air for any length of time becomes contaminated due to the moisture absorbed from the surrounding air and cannot be used. Any oil that is removed from a system should be discarded. NEVER reuse refrigerant oil in a system, always use new oil. Be sure that any containers from which new oil is taken are sealed immediately after drawing out the needed amount. Whenever oil is removed from a system, it should be checked for discoloration and odor. If either or both are present, it means that moisture is present in the system and the moisture is allowed to get into the oil in a refrigeration system sludge or varnish will form which will cause damage to the unit.

As was stated earlier, refrigerant oils are rated by viscosity to operate at certain temperatures. Because of this, you should check the technical manual for the particular system you are working on before putting oil into the system. In this way, you will ensure that you are using the proper oil for the temperatures at which the system operates.

In the event that you are unable to ascertain the recommended oil, the viscosity of oil indicated in figure 2-14 may be used for most applications.

SERVICE CONDITION	REFRIGERANT	VISCOSITY
Compressor temperature		
Normal	All	150 150/additives
High	Halogen Ammonia	150/additives 300 300/additives
Evaporator temperature		
Above 0 F.	Halogen	150 150/additives
	Ammonia	300
0 F to -40°F	Halogen	150 150/additives
	Ammonia	150 150/additives
Below -40°F	Halogen	150 150/additives
	Ammonia	150 150/additives
Automotive compressors	Halogen	500

Fig 2-14. Oil viscosity.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1 What is the important aspect of lubrication in the maintenance of the mechanical components of a refrigeration system?

2. Define viscosity of lubricating oil.

3. List the two principal methods of proper compressor lubrication.

a.

b.

4. State the purpose of an oil separator in a refrigeration system.

5. List the three main categories of refrigerant oils.

a.

b.

c.

Work Unit 2-6. SAFETY AND FIRST AID

STATE THE PRECAUTION REQUIRED WHEN WORKING WITH HIGHLY TOXIC REFRIGERANTS.

STATE WHAT SHOULD BE DONE TO A PRESSURIZED SYSTEM BEFORE OPENING THE LINES OR REMOVING PLUGS.

SPECIFY THE TYPE OF TREATMENT PROVIDED IF REFRIGERANTS COME IN CONTACT WITH THE SKIN.

Most refrigerants are nontoxic; however, all refrigerant gases are dangerous in the absence of oxygen or in high concentrations per given volume of air. Whenever gases or highly volatile liquids are used, make certain that the area is well ventilated. R-12, for example, is in contact with an open flame when investigating a leak with the halide leak detector, insure that you do not inhale the fumes that are produced.

Since many refrigerants do not emit disagreeable odors, it is highly possible to work in an area where there is a considerable amount of refrigerant vapors without being aware of it. Refrigerant vapors, when breathed, cause irritation and conjesture of the lungs and bronchial tubes, often accompanied by coughing and vomiting. If enough refrigerant vapor is breathed, suffocation might result. This occurs because refrigerants are heavier than air and they will replace the air in the area of the system. This is very dangerous because if the air you breathe does not contain at least 19.1 percent oxygen, you would become unconscious. Whenever you are working around vaporized refrigerant gases, take time out regularly to breathe some fresh air and allow your lungs to clear. Also, it is very important for you to wear a gas mask, if you are working on a system that is known to contain a highly toxic refrigerant.

Refrigerants, as they vaporize, will remove heat from any surface in which they make contact. If any liquid refrigerant comes into contact with your skin, the exposed area should be treated the same as for frostbite. Remove the victim to the warmest available place. Do not handle the affected area. Immerse the affected area in warm, not hot, water for about 10 minutes. If warm water is not available, make every attempt to warm the affected area by using your body's heat. If possible, keep the affected area slightly elevated. Keep the affected area dry and the victim warm. Do not rub or massage the affected area. Also, do not apply ice or cold water to the affected area. The victim must receive medical attention as soon as possible. REMEMBER, an individual involved in an accident involving refrigerants should be immediately taken to a doctor.

For your own personal safety, ALWAYS wear goggles and gloves when working on units, especially when charging and discharging a unit or system. These items will protect your eyes, skin, and hands in case of a sudden leak.

Refrigerant oil contained in a hermetic compressor which has had the motor burned out may be very acidic. This oil should NEVER be allowed to touch the skin because it may cause an acid burn.

The following is a list of safety precautions that you, as a refrigeration technician, should follow when working on a system or handling refrigerants:

- Keep a gas mask at the entrance of an area in which there are known toxic refrigerants in the unit or system.
- Keep refrigerant liquids and vapors away from your eyes and skin.
- Whenever your are testing for leaks or transferring refrigerants, wear a gas mask and or goggles, depending on the type of refrigerant being used in the system undergoing repairs.
- When handling chemical cleaning agents, ALWAYS wear goggles and rubber gloves.
- Flame-type leak detectors should NEVER be used on systems that use any type of refrigerant other than the halogen-type refrigerants (R-12, R-22, etc.).
- NEVER use a torch or other open flame to heat a cylinder or a system that contains liquid refrigerants.
- Store refrigerant cylinders in a cool, dry place.

- DO NOT expose refrigerant cylinders to the direct rays of the sun for a long period of time.
- ALWAYS use scales when you are filling refrigerant cylinders to prevent filling them beyond their capacity.
- ALWAYS reduce the internal pressure of a system to 1 or 2 psi before opening lines or removing plugs.
- ALWAYS use a pressure gage to determine pressure in a system or unit.
- NEVER open a system when it is in a vacuum.

Accidents occuring to refrigeration technicians are usually of the following types and may be prevented with the use of proper safety precautions:

- Physical injuries by mechanical means.
- Electrical injuries.
- Burns and scalds.
- Injuries form fire and explosions.
- Disabilities caused by toxic gases.

Even though most moving parts on refrigeration equipment provide protection for personnel through guards, trip switches, and other automatic protective devices, alertness on the part of the maintenance personnel is still necessary. Gloves, ties, and loose clothing should NEVER be worn around moving machinery. Tools should be kept clean and in good condition, with particular attention to the sharpness and squareness of screwdriver blades. Box wrenches should be used in preference to open wrenches because there is less danger of slippage. Before repairs are undertaken, it is advisable to open all electrical switches controlling the equipment and tag or lock them to prevent short circuits or accidental starting of equipment.

Voltage used in the operation of refrigeration equipment ranges from 120 to 480 volts. A high-horsepower centrifugal machine may operate from a 240/416 volt power line. Severe electrical shocks, often fatal, are common in carelessly managed shops. All switches and electrical devices and lines should be checked frequently. When liquids are spilled on floors, fatal grounding through the human body is possible if exposed electrical connections are touched by maintenance personnel.

Care should be exercised when using cleaning solvents, especially when the temperature of the air or of the parts being cleaned is in excess of 100° F. Again, good safety practices dictate adequate ventilation of the area. Keeping equipment clean and free of oil on the exterior also contributes to reducing the hazards of fire or explosion.

When undertaking service operations that will involve refrigerants, other gases, solvents, or the repair of electrical parts, it is good practice to always have a portable fire extinguisher at hand.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is an important precaution required when you are working on a system which contains a highly toxic refrigerant?

____

____

2. Prior to opening the lines or removing plugs on a pressurized refrigeration system or unit, what should you do first?

____

3. In the event that a liquid refrigerant comes in contact with your skin, how should you treat the affected area?

    ____

SUMMARY REVIEW:

In this Study Unit, you learned to identify the primary and secondary refrigerants and their properties. You have learned the importance of refrigeration charts and how to use them. You have also learned how to properly mark and store cylinders, transfer, and measure refrigerants, lubricants, and the safety procedures necessary when handling refrigerants.

Remember, a primary refrigerant is one that acts directly on an area or surface even though it is in a sealed system. Some primary refrigerants are R-12, R-22, R-11, and R-502. Primary refrigerants must be safe to use, they must accomplish the purpose that the system is designed for, and they should operate at pressures as close to atmospheric pressure as possible.

A secondary refrigerant is an agent such as air, water, or brine. It must first be cooled by an external source and then circulated over the area to be cooled. Remember, a secondary refrigerant cannot be used in the primary system.

Refrigerant charts are important. With their proper use, they can save you a lot of time and trouble. You should know how to use them because they will tell you, at a glance, the proper refrigerant to use, the amount to use, the pressure at which they operate, and the amount of heat required to change the refrigerants state.

The marking and storage of refrigerants (or for that matter any industrial gas) are extremely important. If improperly marked or stored, industrial gas cylinders can prove to be extremely hazardous to life and limbs. Remember the do's and don'ts of marking and storing refrigerants.

Always use the proper method for transferring refrigerants from a supply cylinder to a service cylinder (drum). NEVER try to guess at the amount of refrigerant that you are placing in a cylinder. NEVER overfill any refrigerant cylinder.

Be sure that you are using the proper lubricant for the system and refrigerant. Lubricants are refined to different viscosities for use with refrigerants that operate at certain temperatures. Charts are available and must be used to ensure that the proper lubricant is used.

Because of the pressures and temperatures at which refrigerants operate and the fact that some refrigerants are toxic, all safety precautions must be observed. Be familiar with the proper first aid procedures for overexposure to refrigerants, both gases and liquid, in the event you are required to provide first aid to save a fellow Marine.

Answer to Study Unit #2 Exercises

Work Unit 2-1

1. They are heat carriers. Which means, they absorb heat at a low temperature and when compressed to a higher temperature, they release the absorbed heat to a cooling medium.

2. a. Heat

    b. Temperature

    c. Pressure

3. a. Flammability

    b. Explosiveness

    c. Toxicity

    d. Stability

4. a. Boiling point
   b. Freezing point
   c. Miscibility (Oil solubility)
   d. Critical Pressure
   e. Critical Temperature

Work Unit 2-2

1. Fluids used in air-conditioning and refrigeration mechanical systems that absorb heat.
2. c.
3. d.
4. a.
5. stability, pressures and temperatures
6. d.
7. c.
8. -41°F
9. b.
10. Soap solution, halide torch, electronic leak detector
11. Flushing agent
12. 24 inch vacuum
13. -50.1°F
14. reciprocating
15. A low boiling point

Work Unit 2-3

1. 209.9 psig
2. 63.27 psig
3. 92.67 Btu/lb
4. 0.4043 lb/ft^3
5. 108.33 Btu/lb
6. 109.8 psia
7. 860.14 pounds per hour

Work Unit 2-4

1. personnel injury and property damage
2. a. Name of gas

   b. Proper handling precautions
3. Weight
4. 85% of its capacity
5. ice and snow
6. direct rays of the sun
7. 120°F

Work Unit 2-5

1. To reduce friction resulting from moving components of the system
2. Simply stated, it is the thickness or thinness of the oil
3. a. The splash system

   b. The force-feed or pressure system
4. To return the oil to the compressor as soon as possible
5. a. Paraffin base

   b. Naphthene base

   c. Mixed base (Paraffin and Naphthene)

Work Unit 2-6

1 Wear a gas mask

2. Reduce the pressure in the system to 1 or 2 psi before opening the system.
3. Treat the affected area as you would for frostbite.

STUDY UNIT 3

REFRIGERATION SYSTEMS AND COMPONENTS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY VARIOUS REFRIGERATION SYSTEMS AND THEIR MAJOR COMPONENTS. YOU WILL ALSO IDENTIFY THE VARIOUS FEATURES AND CONSTRUCTION OF THE COMPONENTS THAT COMPRISE THE COMPRESSION REFRIGERATION SYSTEM AND THE MAINTENANCE THAT THESE COMPONENTS REQUIRE.

This study unit will describe and illustrate various refrigeration systems. Refrigeration systems may be classified in numerous ways: by the type of refrigerant control, motor control, compression system, absorption system and so on. It is important that you become familiar with the fundamental operating principles of the common systems described within this study unit. The illustrations contained within are not intended to show the exact components and uses of actual units. Instead, they explain the fundamentals of construction and operation. For detailed instruction and the actual uses of various units you should consult the appropriate technical publication for the item of equipment in question.

Work Unit 3-1. REFRIGERATION SYSTEMS

LIST FIVE TYPES OF REFRIGERATION SYSTEMS.

NAME THE MOST COMMONLY USED REFRIGERATION SYSTEM EMPLOYED TODAY.

LIST THE MAJOR COMPONENTS OF A MECHANICAL REFRIGERATION SYSTEM.

The types of refrigeration system used by your grandfathers was, in all probability, an ice refrigerator, also referred to as an ICEBOX,see figure 3-1 using the ice system of refrigeration. The usual ice refrigerator was an insulated box equipped with a holding area at the top for blocks of ice. Shelves for food were located below the ice compartment. These shelves were constructed so that air could circulate through the refrigerator.

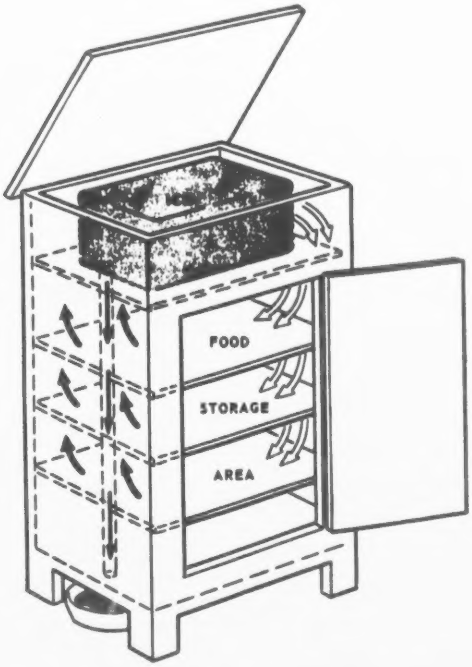


Fig 3-1. Ice refrigerator.

As you have learned earlier, heat is transferred from a higher temperature to a colder temperature. In the ICE refrigerator system, the items placed in the storage area were of a higher temperature than that of the ice; therefore, the heat was transferred to the ice, notice the dark arrows in figure 3-1. Cold air would flow downward, notice the light arrows in figure 3-1, from the ice compartment and cool the items in the storage area. The cool air would absorb the heat from the items stored and rise from the bottom of the box, up the sides and back of the box to the ice compartment, over the ice, giving up the heat that was absorbed and returning it to the storage area to repeat the cycle.

The ice system is by far the simplest system of refrigeration. It has the advantage of maintaining the interior of the box at a fairly high humidity. Foods stored in this type of refrigerator do not dry out rapidly. Temperatures inside an ice refrigerator are controlled by the flow of air over the ice and through the insulated box. The normal range of temperatures for this type of system is between 40° and 50° F.

Another simple refrigeration system is the EVAPORATIVE system. You have learned in the previous study units that as a fluid evaporates as it absorbs heat. Evaporation of water is a good example. This is why you perspire. The evaporation of moisture from your skin surface helps to keep you cool. Another very good example of this is rubbing alcohol. If you were to rub the back of your hand with rubbing alcohol it would feel cool to you. This is due to evaporation. The rubbing alcohol absorbs the heat from the area in which it came into contact. Any substance in which the heat is removed will feel cool or cold.

Perhaps you have experienced another common application of this principle known as the "DESERT BAG." The desert bag is used to keep drinking water cool. The bag is constructed of a tightly woven material. Once it is filled with water, some water will seep through since the bag is not waterproof; thus, the outside of the bag will be moist. Under certain conditions, primarily in the desert, where it is usually hot and dry, the moisture on the surface of the bag evaporates rapidly, thereby keeping the water inside cool. In certain parts of the world where these conditions exist daily, drinking water must be cooled or you would not be able to drink it due to its extreme heat content. Since surface water in the desert sometimes reaches 130° to 150° Fahrenheit, the desert bag is a convenient method which is used to cool drinking water.

DRY ICE refrigeration system consists of blocks and/or slabs of solid dioxide, which are made in various shapes and sizes to be used to absorb heat. Dry ice (solid carbon dioxide) changes directly from a solid to a vapor without changing to a liquid state prior to vaporization. It is, therefore, said to sublime. Sublime means "to convert a solid substance by heat into vapor, which, on cooling, condenses again to a solid form, without apparent liquefaction."

Dry ice should NEVER be handled with bare hands. It will cause instant freeze burns. ALWAYS wear heavy gloves. Normally, dry ice is stored in heavily insulated material to prevent you from coming into direct contact with it.

Figure 3-2 shows a common method of using dry ice as a frozen food refrigerating device. A good example of this is during the summer camping season when dry ice is used by campers to keep perishable foods from spoiling during the trip. The dry ice is usually packed so that the ice is either on the top or sides of the perishable items or the item to be kept cold. Carbon dioxide (dry ice) as it absorbs heat, changes to a vapor and keeps the items of food cold. The dry vapor tends to replace the atmospheric air in the storage container which, in turn, preserves the food.

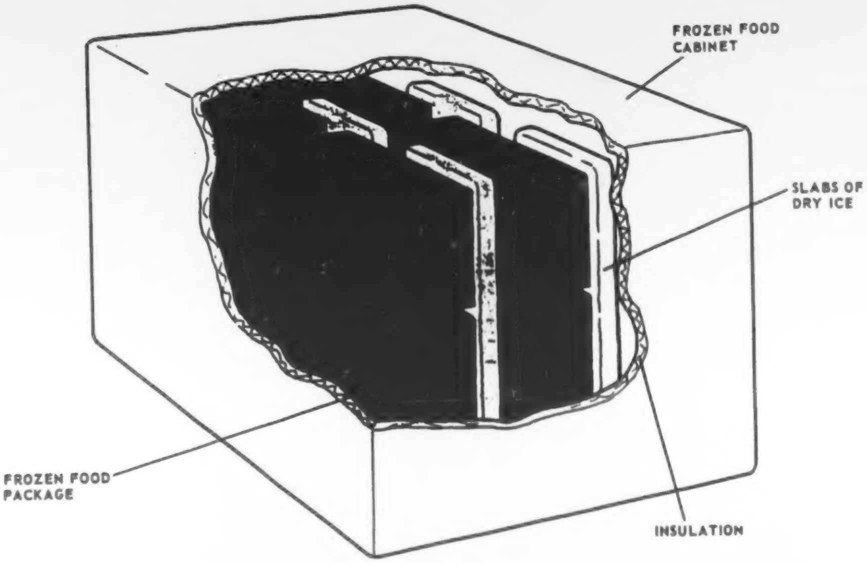


Fig 3-2. Dry ice refrigeration system.

The third refrigeration system that you will learn is called the ABSORPTION system. The absorption system is unique in that, through the use of a flame, it removes heat from a compartment, and the moving parts of the system are a few valves and gages. This principle was first discovered in 1824 by Michael Faraday. Faraday was conducting experiments trying to liquefy certain "fixed" gases (gases which could only exist in vapor form). Among these gases was ammonia. Faraday knew that silver chloride, a white powder, had the peculiar property of absorbing large quantities of ammonia gas; therefore, he exposed the silver chloride to dry ammonia gas. After the silver chloride had absorbed all the gas it could, he sealed it in one end of a test tube shaped like an inverted "V." He then applied heat to the end containing the sliver chloride and ammonia and placed the other end in cool water, see figure 3-3. The heat released ammonia vapor and drops of colorless liquid began to appear in the cool end of the tube. This was the first time liquid ammonia was produced. Faraday continued the heating process until enough liquid ammonia had been produced. He then removed the flame and water so that he could observe the characteristics of the liquid ammonia. Almost immediately the ammonia started to boil vigorously and change back into a vapor. As the ammonia changed to a vapor, the silver chloride began to absorb it once more. Faraday touched the end of the tube containing the boiling liquid and was amazed to find that it was intensely cold. The ammonia, in changing from a liquid to a vapor, had extracted heat from the nearest thing at hand, the test tube itself. Ever since Faraday's experiment, men have used several different chemical combinations in an effort to improve absorption systems.

These efforts have resulted in two types of absorption systems, SOLID and LIQUID. As the names imply, the solid system uses a solid as the absorbent and the liquid system uses a liquid. Of the two the liquid system is or rather was the most popular.

The liquid system, which was used in the Marine Corps many years ago, was water and ammonia, water acting as the absorber and the ammonia as the refrigerant. In this water-ammonia system, it is necessary to include a third ingredient to create a partial pressure to allow the ammonia to evaporate at a low pressure. Dalton's law, which explains the necessity of the hydrogen, states that: the total pressure of gases is the sum of the partial pressures created by each gas in the mixture ($P_1 + P_2 = P_t$). The law further explains that each gas behaves as if it occupies the space alone. For example, if you had a container containing 20 psig (P_1) of oxygen and 30 psig (P_2) of hydrogen, the total pressure in the container would be 50 psig (P_t); and the hydrogen, that is lighter than the oxygen, would rise to the top of the container. Hydrogen in the water ammonia system acts the same way. It mixes with the ammonia vapor and creates the additional pressure in the absorption system's evaporator and then returns to a hydrogen storage tank.

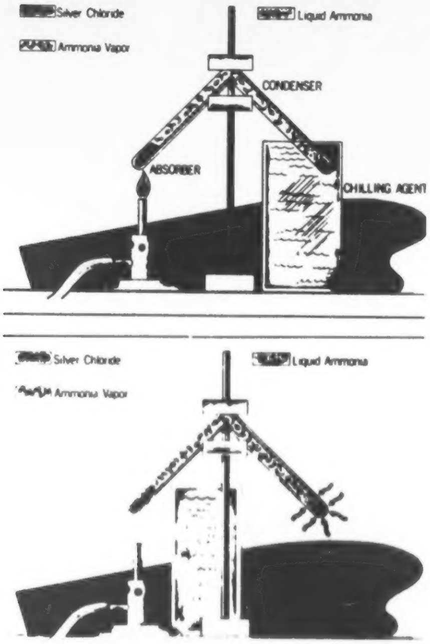
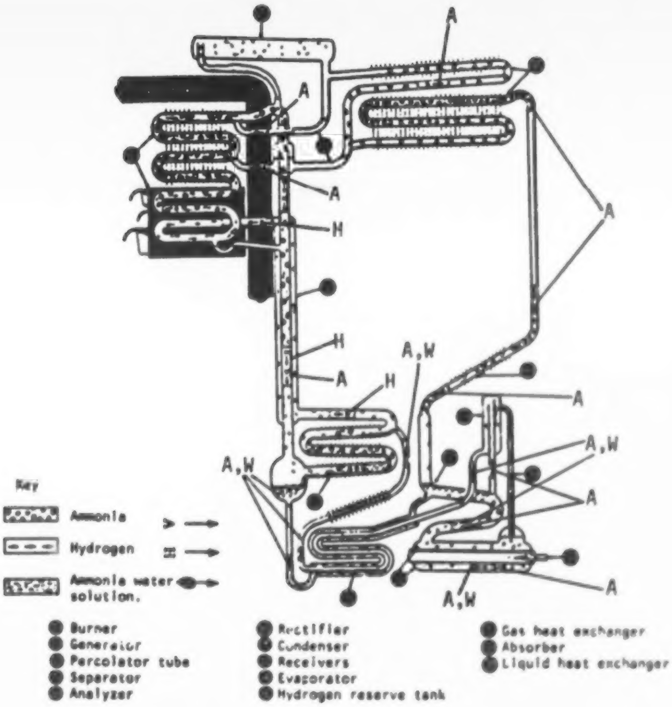


Fig 3-3. Faraday's experiment.

Some of the components of the absorption system are quite similar to those that will be covered in the mechanical compression system. The condensing coil, receiver, and the evaporator are much the same. However, the compressor is replaced by a heater or burner and generator. Refer to figure 3-4 for the identification of the components in the absorption system.

The WATER-AMMONIA absorption system is the simplest of all absorption systems. This particular system requires no moving parts; however, the internal pressures are quite high, they read as much as 200 psi, which means that the construction must be extremely rugged. The system is welded closed and is, therefore, a sealed system. Some absorption systems include metering devices such as expansion valves, thermostats, and gas flow regulators. Expansion valve, in an absorption system, are used for the same purpose and are almost identical to those used in the mechanical system. Thermostats and gas flow regulators are used mainly for automatic operation of the burners and for control of heat in the system. Some absorption systems include automatic defrost equipment which is similar in design and operation to that used in the mechanical systems. Others are defrosted simply by turning off the heat which stops the refrigerant flow.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Key
Ammonia
Hydrogen
Ammonia water solution.
Burner
Generator
Percolator tube
Seperator
Analyzer
Rectifier
Condenser
Receivers
Evaporator
Hydrogen reserve tank
Gas heat exchanger
Absorber
Liquid heat exchanger

Fig 3-4. Water ammonia absorption system (Servel).

As you learned in previous study units, the job of the refrigeration cycle is to remove the unwanted heat from a particular area and discharge it into an area where it is unobjectionable.

The VAPOR COMPRESSION refrigeration cycle is the most common method of heat transfer used today by the refrigeration industry. There are FOUR major components in the compression system of refrigeration: EVAPORATOR, COMPRESSOR, CONDENSER, and the REFRIGERANT FLOW CONTROL DEVICE (metering device).

An understanding of refrigeration theory will make it clear that wherever the production of low temperatures is involved, the same mechanical process must, in general, be employed. As a result, the units that comprise these various systems are quite similar in type and operation. Whether the system is designed for air conditioning or for the refrigeration of foods in the home, freezers, or cold storage plants, equipment such as compressors, evaporators, condensers, and refrigerant flow controls will be present.

Figure 3-5 illustrates a simplified refrigeration system. By applying the theory of latent heat and pressure differences, you can see how low temperatures are produced. This illustration may be applied to any refrigerator regardless of the size or shape.

Every system involves a cycle of one kind or another. You will trace the entire cycle step by step.

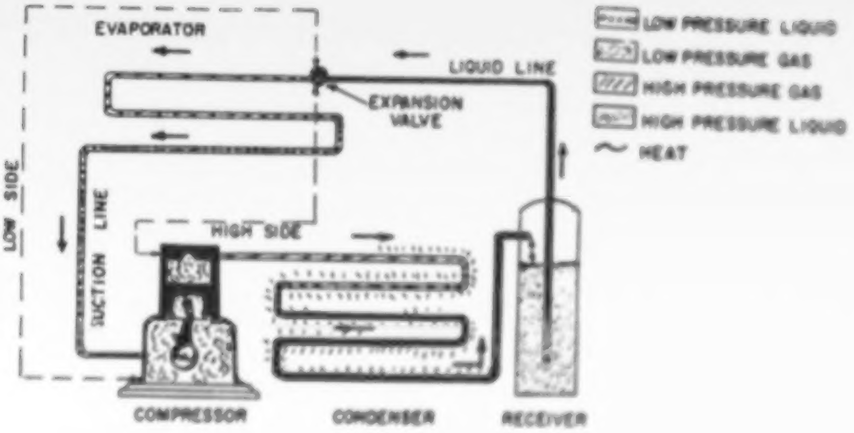

EVAPORATOR
LIQUID LINE
EXPANSION VALVE
LOW SIDE
SUCTION LINE
HIGH SIDE
COMPRESSOR
CONDENSER
RECEIVER
LOW PRESSURE LIQUID
LOW PRESSURE GAS
HIGH PRESSURE GAS
HIGH PRESSURE LIQUID
HEAT

Fig 3-5. Compression system.

Referring to figure 3-5, let's trace the cycle in the compression system. As the piston moves down in the compressor, low-pressure gas is emitted through the valve to fill up the cylinder. As the piston starts up, compression takes place because the gas is forced into a smaller space. As the gas is compressed, heat of compression is added. At the top-most position of the piston, the gas is forced through the exhaust valve into the condenser. The gas is at its highest pressure. The condenser is a series of tubes surrounded by a cooling medium, either air or water. As the gas is forced through the tubes, the heat of compression plus the latent heat of vaporization from the evaporator is dissipated into the surrounding cooling medium.

The removal of heat causes the gas to condense to a high-pressure liquid. This liquid flows into a receiver, which is merely a storage space, and moves up the liquid line to the expansion valve, where the pressure of the liquid is reduced. As a result, it absorbs heat through the walls of the evaporator, lowering the temperature of the compartment to be cooled. As the liquid boils, which is caused by the heat picked up from the cooling compartment, it changes into a low-pressure gas. This low-pressure gas now enters the suction line leading to the compressor. The cycle is now complete.

EXERCISE: Answer the following questions and check your responses against those listed at the the end of this study unit.

1. List the five systems of refrigeration.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

2. What is the most common refrigeration system employed today by the refrigeration industry?

   ____

3. List the four major components of a mechanical refrigeration system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Work Unit 3-2. COMPRESSOR

LIST THE CONSTRUCTION FEATURES OF A RECIPROCATING COMPRESSOR.

GIVEN VARIOUS ROTARY AND CENTRIFUGAL COMPRESSOR FEATURES, MATCH EACH CONSTRUCTION FEATURE WITH EITHER THE ROTARY OR THE CENTRIFUGAL COMPRESSOR.

STATE THE CONSTRUCTION FEATURES OF A HERMETIC COMPRESSOR AND DIFFERENTIATE BETWEEN THE HERMETIC AND SEMIHERMETIC COMPRESSOR.

IDENTIFY VARIOUS COMPRESSOR MAINTENANCE PROBLEMS WITH THEIR PROBABLE CAUSES AND REMEDIES.

STATE HOW TO TROUBLESHOOT HERMETIC SYSTEMS.

STATE HOW TO TEST CAPACITORS AND RELAYS.

The COMPRESSOR is a very important part of the compression system. It is a device that compresses gas, and its function is to remove the heat-laden gas from the evaporator and raise the temperature of the gas above that of the cooling medium. Not all refrigeration systems require the same type of compressor. Some systems require a small volume of refrigerant to be moved with a high difference in inlet and outlet pressure. This difference is called DIFFERENTIAL. Some systems require a large volume of gas moved with a small pressure differential. The application and temperature range dictate the type of compressor to use. The three major types of compressors are: RECIPROCATING, ROTARY (both of these compressors are positive displacement types), and CENTRIFUGAL.

The compressor has two functions within the system:

- Receiving or removing the refrigerant vapor from the evaporator, so that desired pressure and temperature can be maintained.
- Increasing the pressure of the refrigerant vapor through the process of compression, and simultaneously increasing the temperature of the vapor so that it will give up its heat to the condenser cooling medium.

The most common type of compressor in use today compresses gas by means of a reciprocating piston. It is used with refrigerants that have a low volume of gas per pound and a high differential (R-12, R-22, and ammonia). The RECIPROCATING COMPRESSOR is the most reliable, durable, and is the easiest of all the compressors to maintain, see figure 3-6. Refer to figure 3-7 for the operating cycle of the reciprocating compressor.

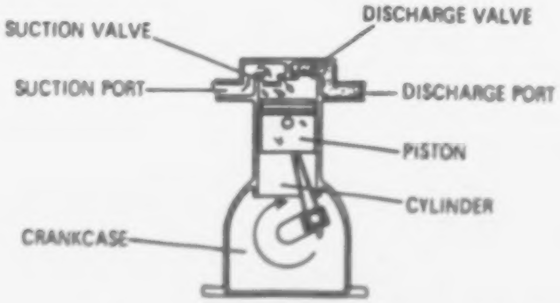


Fig 3-6. Reciprocating compressor.

There are two basic types of reciprocating compressors; SINGLE ACTING (vertical) and DOUBLE ACTING (horizontal). The vertical reciprocating compressor is normally an enclosed type in which the piston is driven directly by a connecting rod, which is moved by a crankshaft. Both the crankshaft and connecting rod are enclosed in a crankcase that is pressure tight to the outside, but open to the refrigerant.

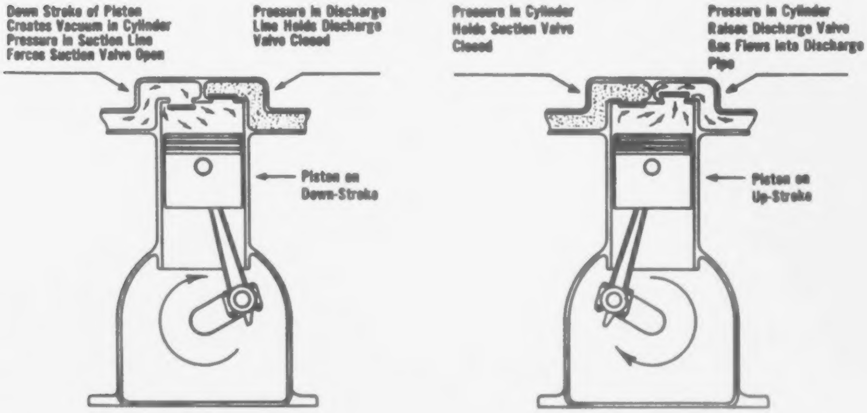

Down Stroke of Piston Creates Vacuum in Cylinder Pressure in Suction Line Forces Suction Valve Open
Pressure in Discharge Line Holds Discharge Valve Closed
Piston on Down-Stroke
Pressure in Cylinder Holds Suction Valve Closed
Pressure in Cylinder Raises Discharge Valve Gas Flows into Discharge Pipe
Piston on Up-Stroke

Fig 3-7. Operating cycle of a reciprocating compressor.

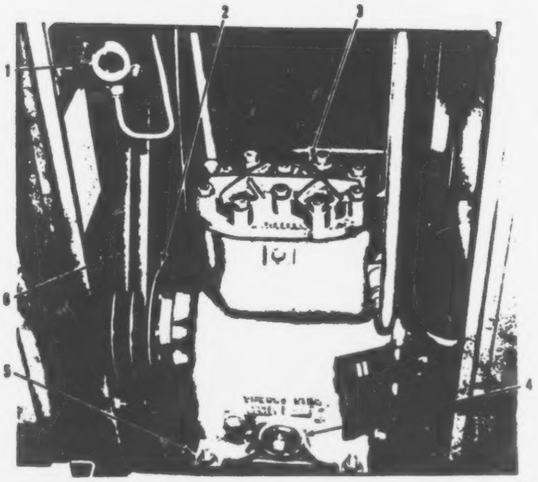
Horizontal compressors usually use crankcases that are vented to the outside, but closed to the system refrigerant. In this construction the piston is driven by a piston rod connected to a crosshead. This crosshead is moved by a connecting rod that operates off a crankshaft.

The reciprocating compressor is highly adaptable to various designs, types, and number and arrangement of cylinders. The number of cylinders may vary from one to 15 and may be arranged in the following manner:

- Inline. If all the cylinders of a compressor are arranged in one straight line, it is called an inline compressor.
- "V." The cylinders of this type will form the letter "V" with the crankshaft located at the bottom of the "V."
- Radial. A radial compressor has all the cylinders located around the crankshaft.
- "W." A "W" type compressor has three banks of cylinders on a common crankshaft.

The bodies of compressors are made of close grained cast iron in one- or two-piece construction. The two-piece construction has the crankcase and cylinders cast separately, then bolted together with a gasket between them. This facilitates the removal and replacement of bad or damaged cylinders. The one-piece compressor is cast in one block with a baseplate under the crankcase. Compressor bodies can be of the OPEN, SEMI-HERMETIC, or HERMETIC type. The open-type compressor has the crankshaft protruding from the compressor body. The shaft is turned by a pulley, belt, and motor. Refer to figure 3-8 for an example of an open type compressor and to figure 3-9 for an example of the hermetic reciprocating compressor.

The type of piston used in refrigeration compressors is determined by the particular valve arrangement. If the suction valve is located in the top of the piston, it is called a trunk-type piston. (The suction gas has to pass through the piston to reach the compression chamber.) If the suction valve is located in the cylinder head, the plug-type piston is used. In large compressors the pistons are equipped with piston or compression rings, while the smaller compressors use only oil grooves.



1. Sight glass
2. Compressor pulley
3. Compressor
4. Compressor oil sight glass
5. Bolt and nut
6. Drive belts

Fig 3-8. Open-type reciprocating compressor.

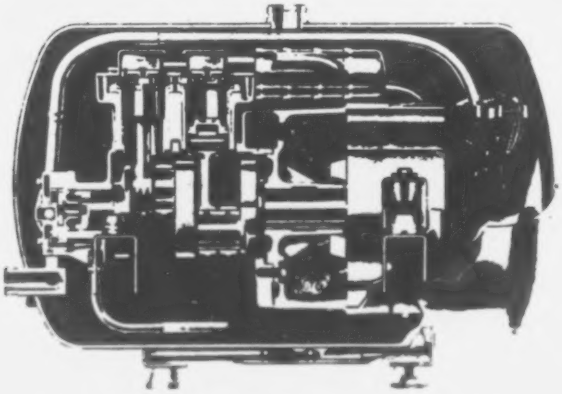


Fig 3-9. Hermetic reciprocating compressor.

Crankshafts are made of drop-forged chrome-nickel steel alloy and are carefully balanced. Some compressors have eccentric crankshafts, which allow for better balancing and less vibration at high speeds. The smaller connecting rod bearings are usually made of bronze, while the larger connecting rod bearings are usually of the insert type. In the eccentric type, the entire eccentric strap is normally made of bearing bronze.

The three most common types of compressor valves are the POPPET, RING, and REED. The poppet valve is used on large, slow-speed compressors. These valves are too noisy, heavy, and cumbersome for use in the modern, highspeed compressors. High speed compressors use the reed valve or the ring valve. These valves are made of high grade, spring steel. Some of the valve shapes are illustrated in figure 3-10.

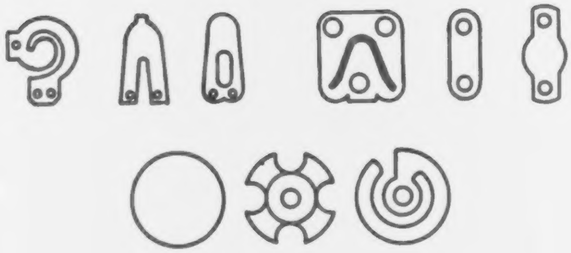


Fig 3-10. Compressor valve shapes.

Some compressors have the suction valve located in the piston, but the normal trend is toward locating both the suction valve and the discharge valve in a VALVE PLATE. This valve plate is located between the compressor body and the compressor head. This arrangement permits the replacement of both valves with minimum difficulty. The suction valve is located on the bottom of the valve plate, and the discharge valve is located on the top of the valve plate. The discharge valves are spring-loaded for safety. If a surge of liquid is drawn into the compressor, it cannot be compressed. A larger opening is needed to allow the liquid to move through without damage to the compressor. This larger opening is provided by the spring-loaded discharge valve.

Some refrigeration compressors are driven by external electric motors or gasoline engines. This requires the crankshaft to go through the body of the compressor. The compressor body contains refrigerant gas and oil that must not be allowed to leak between the body and the shaft. Also, air and moisture must not be allowed to be drawn into the crankcase. To prevent this leakage, a shaft seal is used. The most common shaft seals used on open-type compressors are the rotating bellows, stationary bellows, and diaphragm. Refer to figure 3-11 for a cutaway view of the open-type compressor.

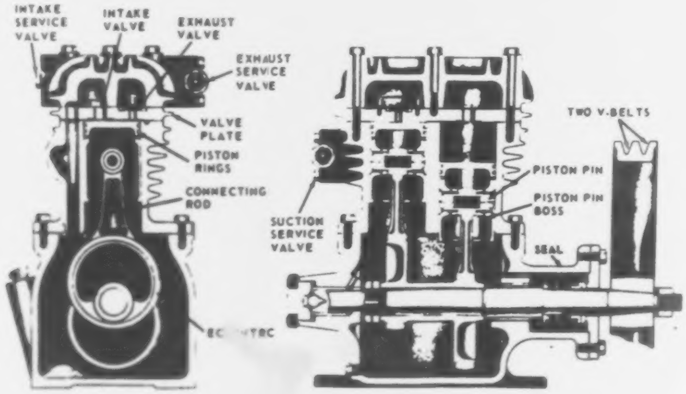


Fig 3-11. Cutaway view of a open-type compressor.

The ROTARY COMPRESSOR compresses the gas by a squeezing action, which results in the gas being reduced in volume and increased in pressure. This compressor has very few moving parts and can be manufactured rather inexpensively. Although small rotary compressors have been used in small domestic units, the large rotary compressors are used extensively in industrial low temperature applications. There are basically two types of rotary compressors; the compressor blade and the rotary blade.

The rotary compressor with the stationary blade consists of a cylinder, a roller, and a shaft. The shaft has an eccentric on which the roller is mounted. A blade is set into the cylinder so that it maintains contact with the roller. The blade is held in place against the roller by a spring. The suction and discharge ports are on opposite sides of the blade. Figure 3-12 illustrates a stationary blade rotary compressor.

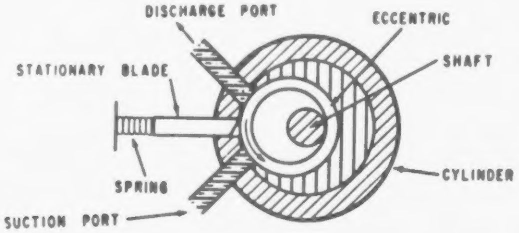


Fig 3-12. A stationary blade rotary compressor.

The rotary compressor with a rotating blade consists of a cylinder and a rotor containing a number of blades. The center of the rotor is eccentric with the center of the cylinder (see fig 3-13). In some designs the blades are spring-loaded to hold them against the cylinder, while others depend on centrifugal force. These compressors are generally operated at motor speed in order to reduce the size of the unit.

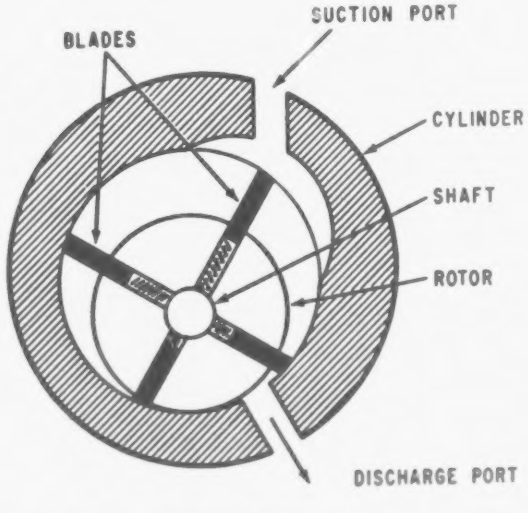


Fig 3-13. A rotating blade rotary compressor.

The CENTRIFUGAL COMPRESSOR, as its name implies, compresses the gas by centrifugal force. It is used with refrigerants that have a relatively large gas volume but small pressure differentials. Although it has a high boiling temperature, refrigerant R-11 usually satisfies these requirements.

Centrifugal compressors are normally constructed with a series of impeller wheels mounted on a steel shaft and enclosed in a cast-iron casing. Most centrifugal compressors have from two to four impeller wheels. These wheels are constructed with two discs (a hub and a cover), with many blades (vanes) mounted radially between them. They are made of stainless steel or a high carbon steel with a lead coating to resist corrosion and erosion. Refer to figure 3-14 for the operating cycle of a rotating blade rotary compressor.

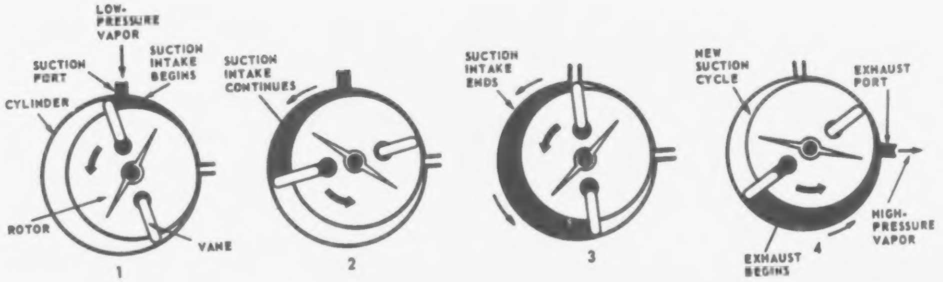


Fig 3-14. Operating cycle of a rotating blade rotary compressor.

Hermetically sealed compressors are basically built like the open-type compressors, except the compressor and the motor are enclosed together in an airtight housing. There are two types of enclosed systems: the hermetic compressor and the semi-hermetic compressor. The hermetic compressor has a welded case that makes it almost impossible to repair by the refrigeration technician. The semi-hermetic compressor has a bolted case that can be disassembled for repairs. One big advantage to the hermetic compressor over the open compressor is that it does not require a shaft seal to prevent the entrance of air and the leakage of refrigerant.

The hermetically sealed reciprocating compressor consists of a cylinder and head, a piston and connecting rod, intake valves, exhaust valves, flywheel, and crankshaft. They may also have service valves and suction strainer. Because the compressor is operating in a closed environment where the temperature range is rather narrow, clearances as small as 0.001 inch are possible between the moving parts.

The piston may be driven in a number of ways. In one of these ways, the crankshaft may be like the kind used in automotive engines. Another type uses an eccentric crankshaft which operates like a cam. Still another is the scotch yoke mechanism, which uses a pin mounted off-center to the crankshaft. A sliding member inside the piston permits the rotation of the pin to be translated into an up and down motion. Variations such as these are possible because the gases being pumped do not produce heavy bearing loads. The piston is made to come as close as possible to the head without touching. Clearance may be as little as 0.01 inch from the top dead center.

Exhaust and intake valves are usually thin disks of steel that seat against shoulders in the valve plate. These valves are sometimes called FLUTTERS or REED valves. Pressure in the cylinder closes the intake valve and raises the exhaust valve on compression. On the intake stroke, pressure in the suction line opens the intake valve, while back pressure from the high-side closes the exhaust valve. Valves are designed to operate at a maximum lift of 0.10 inch. Beyond this point, the valves get noisy.

Fewer moving parts and less vibration are the advantages of the rotary compressor, which is made in two styles. One style uses an eccentric shaft with a blade which is forced against the shaft by a spring. The blades slide back and forth in a slot in the case, between the intake and exhaust. As the shaft turns, it traps a gas charge at the intake and sweeps it around to the exhaust. Oil makes the seal for the blade so that the gas will be compressed.

In another style of rotary compressors, vanes are mounted in slots on the shaft. The shape of the case around the vanes is eccentric. Centrifugal force holds the vanes in continuous contact with the eccentric wall. The inlet port is located in the wall farthest from the shaft, at the spot where a gas charge is picked up between two vanes. As the shaft turns, the space between the shaft and the wall becomes smaller, compressing the charge of gas. The exhaust port is set in the case where the shaft almost rubs against the case. The compressed charge of gas is forced out the exhaust port at this point.

The exhaust valve is a flapper type made of spring steel. A muffler is placed in the high-pressure line to suppress the popping noise that accompanies the release of a gas charge. The suction line has a check valve to prevent gas from leaking back when the compressor is stopped. The suction strainer prevents dirt particles from entering the compressor.

When the compressor fails to work properly, the system will not do the job for which it was designed. This results in loss of food, damage to equipment, or discomfort to personnel, thus creating an added expense to Marine Corps operations.

One of the most common symptoms of a defective compressor is noisy operation. This could be caused by a loose pulley, worn or damaged pistons, worn connecting rods, or improper lubrication. Normally a loose pulley only requires tightening, while defective pistons or connecting rods require a complete overhaul. Improper lubrication, if found in time, would normally only require the addition of oil. One important requirement before adding oil is to check for leaking gaskets or shaft seals.

Another symptoms is a high suction pressure. If this is noticed, the most likely cause is a leaking suction valve. To check for leaking suction valves, front seat the suction service valve and observe the low-side manifold gage. If the compressor cannot pull this small volume down to 20 inches Hg, the suction valves are defective. This can be corrected by installing a new valve plate assembly. If a new plate assembly is not available the old valve plate can be lapped. If a low head pressure is noticed during operation, the most likely cause is leaking discharge valves. A new valve plate assembly is also required for the malfunction.

Another item to check is the drive belt. Inspect its tension and alinement. The belt may be checked by turning the unit off and by placing your finger on the center of the belt. If the tension is correct, you should be able to move the belt up and down approximately 1/2 inch on small units and 1 inch on large units. The tension of the belt is very important, since loose belts will slip and wear very quickly, and belts that are too tight will stretch, weaken, and eventually break. The alinement of the flywheel and motor pulley are also very important for good operation. All belts should run straight and true without vibration. Check to make sure that the motor shaft is parallel with the compressor shaft.

The sealed system preferred for freezers and refrigerators is called a CLOSED or HERMETIC system, because the shell that contains the motor and compressors is welded shut. The motor leads pass through a glass insulator, which is bonded to the metal to insure a joint that will never leak. As was stated earlier, the one big advantage of a hermetic compressor is that there are no mechanical seals to develop leaks. This eliminates at least one trouble-spot from the system used in domestic refrigerators and freezers. However, as you know, there are still enough other trouble-spots to keep a service technician busy.

The best troubleshooter puts his brain to work before reaching for the toolbox. The first step you must take on the job, should be to question the user. Ask, for example, these things:

- When did you first notice this trouble?
- Is this condition intermittent, or is it continuous?
- Does this just happen when a heavy load is placed on the unit, or all the time?

The answers to such leading questions should enable you to determine whether the trouble is being caused by misuse or malfunction. By eliminating outside factors at the beginning, you will know that you are dealing with a fault in the equipment itself. After this, consider the possible electrical troubles FIRST, as they can usually be checked easily and quickly.

There is a logical sequence for making tests on the electrical system. The first check seems so simple that it is often overlooked. Check to insure that the unit is TURNED ON. Remember, the unit cannot operate without electrical power. A quick reference for common faults is given in figure 3-15, together with the possible causes, and their remedies. Such a troubleshooting chart is most useful, since it presents a great many facts in a small place. This information can be found, in greater detail, in the technical manuals for each piece of equipment as there is variation from type to type.

ELECTRICAL TROUBLES (HERMETIC UNITS)

FAULTS	CAUSE	REMEDY
Will not run.	No power.	Close circuit or repair open.
	Defective thermostat.	Replace.
	Defective defrost switch.	Replace.
	Defective defrost timer.	Replace.
	Open overload protector.	Reset or replace.
	Open relay coil.	Replace relay.
	Open motor winding.	Replace compressor.
Runs noisy.	See mechanical troubles.	
Short-cycles and runs noisy	Relay contacts not operating.	Replace relay and check capacitor and bleeder resistor.
	Short circuit or grounded motor winding.	Check and replace compressor.
Unit trips circuit breaker or blows fuse.	Short circuit or ground. *	Check out electrical system.*

*Note: If a fault causes a ground in the box, you can be fatally shocked by touching the refrigerator or the freezer chest!

Fig 3-15. Electrical troubles.

In addition, you sometimes find the solution to a problem while studying a troubleshooting table, even though the specific fault does not appear in the table. Often, in fact, a common fault is passed by because it seems too obvious. The service person may think that a common fault is to easy and could not possibly be the trouble. DO NOT prejudge; instead, make reasonable "guesses" from what you see and from the trouble chart, then test to find out. In the following paragraphs, you will be given a detailed explanation of common troubles to be found in the electrical system.

Check the source of power for voltage to the unit. HOW? With a voltmeter or a multimeter! In the case of a refrigerator, open the door. If the light does not come on, there are several possibilities: (1) the power circuit is incomplete to the unit; (2) the lamp is burned out; (3) the door switch is defective; and (4) the circuit to the unit may be good, but the wires to the lamp and the door switch are broken somewhere in the box. If the lamp lights, you will know that there is power to the unit. However, check the voltage with an accurate voltmeter when you suspect low voltage. REMEMBER, the voltage may vary 10 to 15 volts with changes in the load during the day. Most units will not indicate problems unless the voltage drops below 105 volts.

Make sure that the power cord is disconnected before making a continuity test on the protector. With an ohmmeter or a DC-powered test lamp check for a continuous circuit through the overload protector. If it tests OPEN, you have found at least one trouble spot which will prevent the compressor motor from operating. Replace the defective overload protector and check the unit for normal operation. Many compressors have the overload protectors located inside the shell. A distinctive label on the compressor is used to indicate an internal mounting. Placing a protector inside the shell has the effect of extending the cooling period after an overload trip. REMEMBER, when checking an overload protector mounted inside, allow the compressor sufficient time to cool so that the protector has a chance to automatically reset itself. How long is "sufficient time"? When you can rest your hand comfortably on the shell, the compressor should have cooled enough for you to make a valid test of the overload contacts.

Check, too, all control switches for proper operation, since one open switch will prevent the unit from operating. Such items as thermostats, defrost controls, and freezestats are all designed to open and close the primary circuit. REMEMBER the function of the item you are checking, because an open circuit may not mean that the device is defective. A thermostat should show an open circuit if the feeler bulb is colder than its operating point. A defrost control will be open if the time is in the defrost cycle. Some defrost systems have a reset which is actuated by an increase in temperature above a set point. A freezestat will show an open circuit when it senses a temperature lower than its operating point. You can check the operation of a device by raising or lowering its temperature. Check a thermostat by placing the feeler bulb in a glass of ice and water. Connect an ohmmeter or test light across the contacts so that the time of opening and closing can be observed. Place a thermostat in a glass of water and read its temperature at the time the contacts open. Remove the ice and add warm water slowly till the contacts close. Again, read the temperature of the water. Replace the thermostat if it does not conform with the manufacturer's specifications.

A hermetic system can be checked quickly with a motor-stat analyzer, see figure 3-16. It will check for continuity in motor windings, for shorted windings, and for grounded windings. It can also be used to start a motor or to reverse the direction of rotation. The analyzer contains capacitors which can be used in the motor circuit to increase its starting torque. Higher starting torque or momentary reversing are two ways of unlocking a compressor which for some internal reason cannot be started normally. When an analyzer is not available, plug the refrigerator cord into an outlet and test for voltage at the terminal block where the cord terminates. There should be voltage at the terminals if the cord is good. If the motor runs, you should use a clamp-type ammeter to check for correct motor current. Next, you must unplug the cord and make some continuity checks with a test light or an ohmmeter. Unless you are familiar with the electrical system, you will need a wiring diagram for the unit that you are testing.

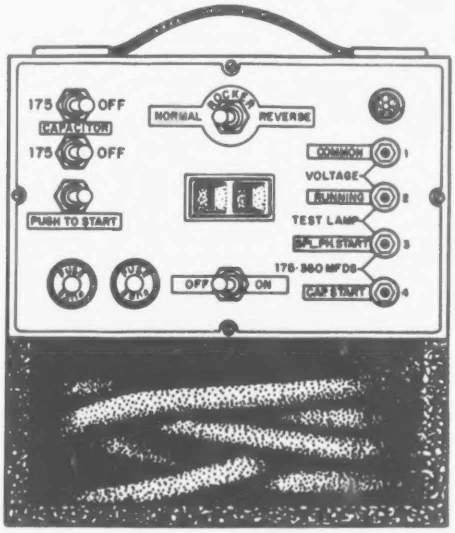


Fig 3-16. Motor-stat analyzer.

Some compressors have an electrical heater in the crankcase to prevent condensing of the refrigerant during the off cycle. Liquid refrigerant can cause slugging and damage the compressor. Be sure of the type of motor used before you attempt to trace the motor circuit. Determine what type of relay (hot-wire, current, or potential relay) is in the unit. After you have checked the diagram and understand the circuit, you will be ready to check out that specific motor.

For the purpose of our explanation, refer to figure 3-17, which illustrates the circuit for a potential relay. You will use the compressor motor circuit shown in figure 3-17 to identify the motor's terminals in the following discussion. Make a continuity check terminals "C" to "S" and between "C" and "R". A test lamp should light normally in each case, if the windings are good. An open circuit is indicated when the lamp fails to light. Note that this test is valid only if direct current is used to energize the test light. If alternating current is the only power available for the test lamp, the common connection at "C" must be disconnected. Otherwise, the closed contacts of the relay and the capacitor will make a complete circuit. Disconnecting "C" is not necessary when checking with an ohmmeter, because it uses direct current from self-contained batteries. The reason is that a capacitor blocks direct current, while it allows alternating current to flow.

To test for a grounded motor winding, check from terminal "C" to an unpainted part of the compressor-motor shell. Use an ohmmeter to measure the resistance of the motor windings to test for a shorted coil. Readings should compare to the specifications of the manufacturer.

A severely shorted coil would be indicated by tripping of the branch circuit breaker or by blowing the fuse when the unit is plugged into the voltage outlet. If tests indicate that the motor windings are at fault, replace the hermetic unit. If the motor runs but overheats during operation, a current draw test with a clamp-type ammeter will give you an indication of condition. Motor current should be within 10 percent of the name plate rating on the unit. The name plate may give two amperage figures, such as FLA 3.6 and LRA 18.0. The FLA stands for "full load amperage," while LRA stands for "locked rotor amperage." If the current exceeds the name plate rating by more than 10 percent, it is considered unsatisfactory, and the hermetic unit must be replaced. A motor drawing its LRA rating indicates that the rotor is not turning. Conditions inside the sealed unit will also be indicated by unusual vibration and noises. Figure 3-18 shows some of the most common mechanical troubles. Most problems that occur are due to a faulty hermetically sealed system requiring a complete replacement of the compressor.

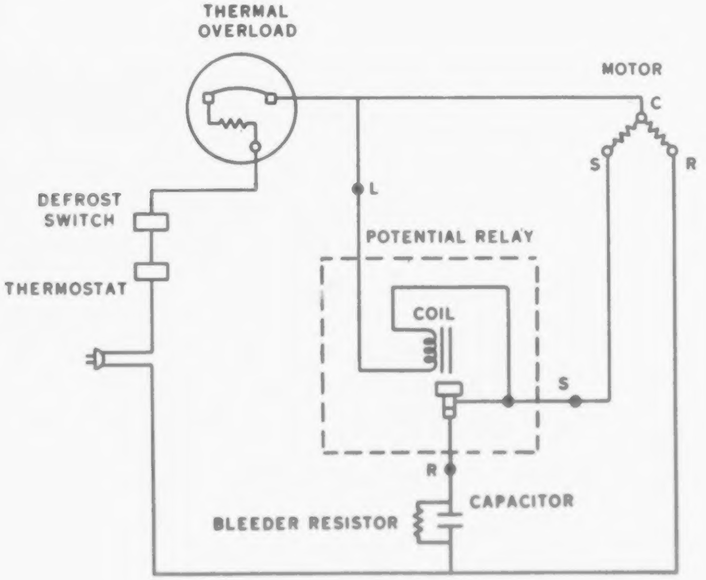


Fig 3-17. Potential relay circuit.

MECHANICAL TROUBLES (HERMETIC UNITS)

Fault	Causes	Remedy
Fails to run	Locked rotor.	Repalce compressor.
Fails to cool or runs continuously	Broken valves	Replace compressor.
	Restrictions:	
	- kink or pitch.	Cut out and replace.
	- moisture.	Dry and recharge.
	Low on charge.	Find leak, repair, and recharge.
Vibration.	Loose motor mounts	Tighten.
	Loose tubing mounts.	Tighten.
	Shipping bolts installed.	Remove.
	Uneven floor.	Adjust feet.
Noisy compressor.	Defective part (internal).	Replace compressor.
Lost charge	Punctured coil or leak.	Repair and recharge.

Fig 3-18. Mechanical troubles.

In the following you will be given two methods for testing a capacitor. When the capacitor can be disconnected from the circuit and the bleeder resistor, a reasonable test is to charge and then discharge it with its normal voltage (not over 120 volts). Charge it by momentarily applying voltage to its terminals. Then use a piece of insulted wire to short-circuit the terminals. A hot spark indicates that the capacitor is able to hold a charge. Some capacitors have a bleeder resistor of between 15,000 ohms and 30,000 ohms which is in the form of an integral part that cannot be disconnected. This type of capacitor may be checked by connecting an ammeter and a 10-, 15-, or 20-amp fuse in series with the capacitor. Apply 120 volts to the capacitor just long enough to read the ammeter. If the fuse blows, the capacitor is shorted and must be replaced. Use a fuse large enough to carry the current, and make sure that the current will not be so great as to drive the ammeter needle off the scale. For example, a 20-ufd capacitor at 120 volts should draw less than 11 ampere, while a 400-ufd capacitor at 120 volts will draw 18 amperes. In making the test, apply voltage to the capacitor just long enough to read the ammeter. The current measured should be within 20 percent of that determined by the formula below where ufd is the rating in microfarads and "V" is the normal applied voltage. The number 2,650 is a constant for 60-cycle current, while 3,180 is the constant for 50-cycle current:

Capacitor test

for 60-cycle $$\text{amps} = \frac{\text{ufd} \times \text{V}}{2{,}650}$$

for 50-cycle $$\text{amps} = \frac{\text{ufd} \times \text{V}}{3{,}180}$$

A defective capacitor must be replaced by one of the same voltage and farad rating or the equivalent as specified by the manufacturer.

Before you test a system's relay, you must know the type of relay that you are looking at. You must have a schematic diagram that shows the hookup of the relay but does not identify it by name. You should be familiar enough with the common types to identify them by their characteristics. A fan motor is used in some units for forced air circulation. The diagram in figure 3-19 shows an example of a relay and a fan motor in the same circuit. The fan motor must be disconnected before testing the relay.

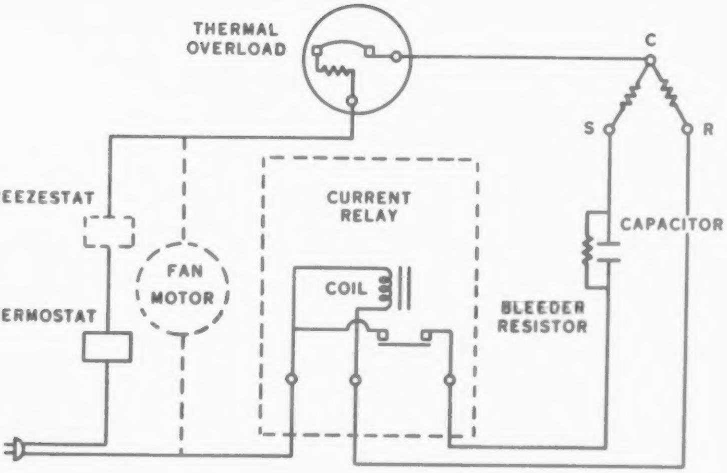

THERMAL OVERLOAD
C
S
R
FREEZESTAT
CURRENT RELAY
CAPACITOR
FAN MOTOR
COIL
THERMOSTAT
BLEEDER RESISTOR

Fig 3-19. Relay and fan motor diagram.

Figure 3-20 shows a type of hot-wire relay that has two bimetal strips, two resistors or heaters, and two sets of contacts. Both sets of contacts should be closed when the relay is not energized. The start contacts should open as soon as the motor reaches operating speed. You can verify opening of the start contacts with a voltmeter, which should read line voltage across the start contacts. A zero reading will indicate that the contacts are not opening.

The current relay shown in figure 3-19 can be checked for continuity through the coil and for an open circuit across the contacts when it is not energized. The contacts close on starting but should remain open while the motor is running. Use DC (such as with an ohmmeter) to test across the relay contacts, as AC can feed around through the motor windings and the capacitor, giving a false reading of continuity.

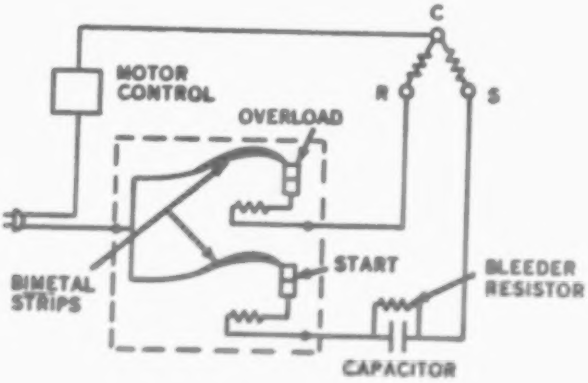

C
MOTOR CONTROL
R
S
OVERLOAD
START
BLEEDER RESISTOR
BIMETAL STRIPS
CAPACITOR

Fig 3-20. Hot-wire relay.

The potential relay as shown in figure 3-17, must be isolated from the compressor motor before testing. Disconnect the "R" and "S" leads at the terminals on the relay. Check the Relay contacts between "R" and "S" for continuity. The contacts are normally closed, thus, the test should show a complete circuit. A test between "S" and terminal "L" should also show a complete circuit through the coil of the relay. If either test shows an open circuit, the relay is defective and must be replaced.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are the two types of reciprocating compressors used?

   a. ______________________________

   b. ______________________________

2. What important construction feature differentiates these two compressors in question #1?

   ____

   ____

3. Identify two of the three construction features of the compressor body for reciprocating compressors.

   a. ____

   b. ____

4. What type of compressors use reed or ring valves?

   ____

5. Each of the following phrases pertains to either the rotary or centrifugal compressor. As applicable insert an "R" for rotary or "C" for centrifugal in the spaces provided.

   _____ a. Compresses gas by a squeezing action.

   _____ b. R-11 normally is used.

   _____ c. Uses two out of four impeller wheels.

   _____ d. Blades are held in place by spring action.

   _____ e. Constructed with roller, shaft, and cylinder.

   _____ f. Vanes are constructed of stainless steel.

   _____ g. Vanes and shaft are enclosed in a cast-iron casing.

   _____ h. The rotor and cylinder are eccentric to each other.

6. What is the difference between the hermetic and the semi-hermetically sealed compressors?

   ____

   ____

   ____

7. What is one advantage a hermetic compressor has over an open compressor?

   ____

8. Indicate whether the following phases pertain to a hermetic reciprocating compressor or a hermetic rotary compressor by placing reciprocating or rotary in the space provided after each phase.

a. The shape of the case around the vanes is eccentric. ________

b. An eccentric crankshaft is used. ________

c. A scotch-yoke mechanism is used. ________

d. A minimum of vibration is an advantage. ________

e. There may be only 0.001 inch of clearance at top dead center ________

Matching: Column A (items 9-12) contains compressor symptoms. Column B (a through d) contains probable causes of each symptom. Column C (A through D) contains the appropriate maintenance action for each symptom. Match the compressor symptom in column A to its probable cause in column B, and, accordingly to its corrective maintenance action in column C. Place your answer to each of the items in the space provided. There will be two answers per item.

Column A	Column B	Column C
Compressor symptoms	Probable causes	Maintenance action
9. Noisy Compressor	a. Improper tension	A. Change belt
________	b. Leaking discharge valve	B. Add oil
10. High suction pressure	c. Improper lubrication	C. Install new valve
________	d. Leaking suction valve	plate assembly
11. Low head pressure		D. Lap valve plate and insert new valves
________		
12. Stretched drive belt		
________		

13. What is always your first troubleshooting step?

____

14. How would you check a hermetic system for a faulty motor circuit?

____

____

15. State how to test capacitors that can be disconnected from the circuit and resistor.

____

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Work Unit 3-3. CONDENSER AND RECEIVERS

STATE THE PURPOSE OF CONDENSERS AND LIST FACTORS THAT AFFECT THEIR OPERATION.

DESCRIBE THE MAIN TYPE OF CONDENSERS.

SPECIFY METHODS OF MAINTAINING PROPER OPERATION PRESSURE FOR AIR-COOLED CONDENSERS.

SPECIFY CHARACTERISTICS OF THE VARIOUS WATER-COOLED CONDENSERS.

STATE THE PURPOSE AND NAME THE TWO TYPES OF RECEIVERS.

There are many types of condensers in current use; therefore, it is important to know something about their design, operation, and application in a refrigeration system.

The heat that is picked up in the evaporator is disposed of by the CONDENSER. The condenser changes the high-pressure and high-temperature gas to a high-pressure liquid. The rate of heat transfer depends on such factors as the surface area, material, and condition of the condenser and the type, the temperature, and the amount of the cooling medium.

There are three things that take place in a condenser: DESUPERHEATING, CONDENSING, and SUBCOOLING. Before any condensation can take place, the highly superheated gas must have the superheat removed from it. This desuperheating process occurs in the discharge line, in the first few coils of the condenser. After the superheat is removed, the gas is at its saturation temperature. At this point the gas gives up its latent heat and returns to a liquid. This is called the condensing process. After the gas has condensed to a liquid, its temperature is still above that of the cooling medium (water, air, etc.). In the last coils of the condenser, the liquid gives up its sensible heat to the cooling medium. This is known as subcooling.

You can prove the existence of these three conditions by running your hand over a condenser that has been in operation for an hour or so. The top coils will be much warmer than the middle coils, and the middle coils will be a lot warmer than the lower coils.

The type of condenser that is used in a refrigeration system depends on the cooling load of the unit and weather factors of the locality. Condensers can be grouped into broad categories such as: AIR-COOLED, WATER-COOLED, and EVAPORATIVE.

AIR-COOLED condensers use ambient air as the cooling medium. They are normally constructed of steel or copper tubing, and they may be made with or without fans. These condensers use either the natural or forced convection process. Most domestic refrigerators use the natural circulation of air. Their condensers consist of tubing mounted on the back of the refrigerator. By allowing a space between the box and condenser, the air flow is similar to that of a chimney, and no fan is necessary.

Although there are a few disadvantages in using air-cooled condensers, they require much less maintenance than other types of condensers. For this reason, refrigeration systems of 100 tons are being built with air-cooled condensers for use in cooler climates. Among the disadvantages of using air-cooled condensers are greater operating costs and reduced unit efficiency due to higher head pressure. The power needed to drive the condenser fans is sometimes quite excessive. This results in a disadvantage and the condenser fan noise may also become objectionable. All air-cooled condensers must also have adequate ventilation for the best possible results.

The WATER-COOLED condenser uses water as the cooling medium. The capacity is controlled by regulating the amount of water through the condenser. There are certain advantages in using water-cooled condensers. They are compact, they have a higher heat transfer, they use a lower head pressure, and there is an increased condensing unit capacity. Along with the advantages, there are also disadvantages. There is a higher cost in water and in maintaining the cooling tower, and there is a higher cost for installation. Water-cooled condensers are classified into three general groups; SHELL and COIL, DOUBLE TUBE, and SHELL and TUBE.

The SHELL and COIL condenser consists of a welded shell containing a finned water coil. The refrigerant is between the shell and the coil, and the water is inside the coil. The water must be reasonably clean and free from minerals since the coil must be cleaned by the chemicals circulated in the water. Refer to figure 3-21 for an example of the shell and coil condenser.

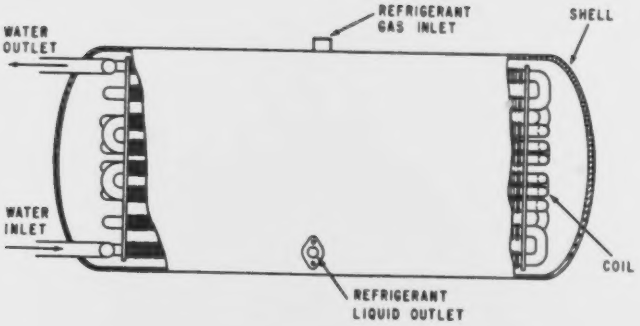
WATER OUTLET
REFRIGERANT GAS INLET
SHELL
WATER INLET
COIL
REFRIGERANT LIQUID OUTLET

Fig 3-21. Shell and coil condenser.

The DOUBLE TUBE condenser, sometimes referred to as the tube-within-a-tube, is illustrated in figure 3-22. The water flows in the opposite direction in the inner tube. The refrigerant is between the inner and the other tube. This counterflow action gives high efficiency. Here again, the water used must be clean and free of minerals as the internal cleaning of the condenser is accomplished by chemicals circulated in the water.

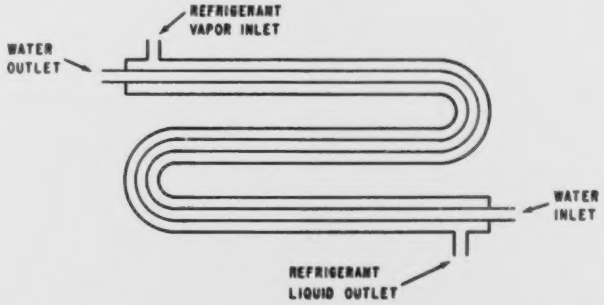
REFRIGERANT VAPOR INLET
WATER OUTLET
WATER INLET
REFRIGERANT LIQUID OUTLET

Fig 3-22. Double tube condenser.

The SHELL and TUBE condensers as shown in figure 3-23, are made of a steel shell with tube sheets at each end. Copper tubing runs from one of these sheets to the other. Iron heads bolt on each end of the condenser. Water flows into one of these heads and out the other, and the refrigerant is between the sheet and the copper tubing. From a maintenance standpoint, this is the best type of water-cooled condenser, since the heads may be removed and the tubes cleaned out mechanically with a revolving brush.

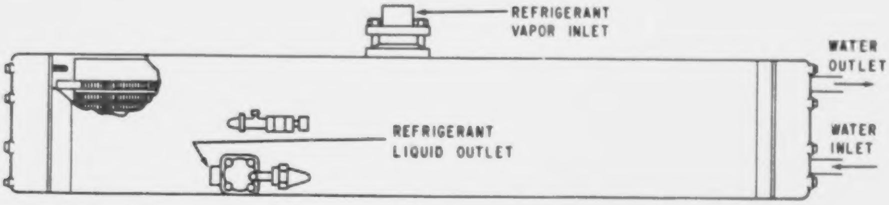
REFRIGERANT VAPOR INLET
WATER OUTLET
REFRIGERANT LIQUID OUTLET
WATER INLET

Fig 3-23. Shell and tube condenser.

The EVAPORATIVE condenser is cooled by water sprayed directly over the condensing coils, refer to figure 3-24. The evaporated water carries away the heat of condensation. The remaining water drops to a sump under the condenser where it is recirculated by a pump. A fan draws over the condenser coils to increase the cooling capacity. Each pound of water evaporating on the condenser removes 970 Btu's of heat from the refrigeration system. This type of condenser is very efficient, and the temperature varies from very hot to very cold in a year's time.

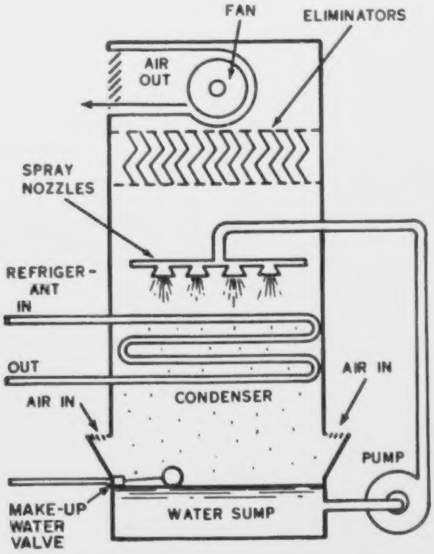
FAN
ELIMINATORS
AIR OUT
SPRAY NOZZLES
REFRIGERANT IN
OUT
AIR IN
CONDENSER
AIR IN
PUMP
MAKE-UP WATER VALVE
WATER SUMP

Fig 3-24. Evaporative condenser.

Immediately following the condenser, in the refrigeration system, is the RECEIVER. The receiver is a storage tank, usually cylindrical in shape, used to hold the surplus refrigerant in the system. A receiver is normally large enough to hold the complete refrigerant charge. This allows work to be performed on the system without the refrigerant being removed from the system. The receiver uses manual or automatic control devices to feed the evaporator at approximately the same rate at which it receives the liquid from the condenser, thus maintaining a required temperature. Refer to figure 3-25 for an example of a horizontal liquid receiver.

There are basically two types of receivers, the VERTICAL and the HORIZONTAL. The inlet to these receivers is normally at the top and the outlet on the bottom. If the outlet is at the top, an internal tube (dip tube) extends to the bottom to maintain a liquid seal at the outlet. This keeps vapor from entering the liquid line. Industrial-type receivers usually have a sight glass (sight level indicator) to check the amount of liquid in the tank; however, small domestic units seldom do. The tank should be about one-third to one-fourth full of liquid refrigerant when the system is in operation. This will leave room for the surplus refrigerant when the system is pumped down.

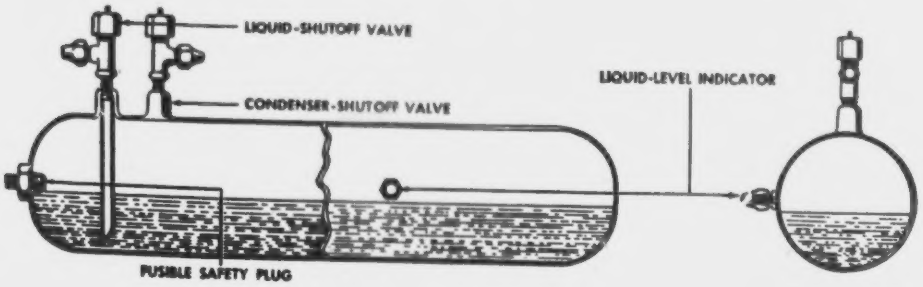

Fig 3-25. Horizontal liquid receiver.

A large system that uses a shell and tube water-cooled condenser refer to figure 3-23, does not need a separate receiver. The bottom one-third of the condenser is utilized as a receiver. This application is referred to as a condenser-receiver. Care must be taken to prevent overcharging the system. If any of the water coils are covered with liquid refrigerant, the head pressure will increase, reducing the compressor efficiency.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What three functions does a condenser perform?

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. List the six factors on which the rate of heat transfer depends.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

3. State the purpose of the condenser.

   ____

   ____

4. What two factors determine the type of condenser to be used?

   a. ______________________________

   b. ______________________________

5. Briefly describe the following types of condensers.

a. Air-cooled - ______________________________

____

b. Shell and coil - ______________________________

____

c. Double tube - ______________________________

____

d. Shell and tube - ______________________________

____

e. Evaporative - ______________________________

____

6. What are the two basic types of receivers?

a. ______________________________

b. ______________________________

7. What type unit does not require a receiver? Why?

____

____

____

8. Why are receivers used in a system?

____

____

Work Unit 3-4. EVAPORATORS

STATE THE PURPOSE OF THE EVAPORATOR AND NAME THE BASIC TYPES AND GROUPS OF EVAPORATORS.

DIFFERENTIATE BETWEEN THE DRY AND FLOODED TYPE EVAPORATORS.

EXPLAIN WHAT IS MEANT BY THE OPERATING CONDITIONS OF THE EVAPORATORS.

DESCRIBE VARIOUS EVAPORATORS IN COMMON USE.

DESCRIBE THE SPECIAL EVAPORATORS TYPES.

If you will remember, earlier in this course it was said that heat moves from hot to cold. This is the basic situation in which the evaporator works.

The evaporator is that part of the refrigeration system within which the refrigerant is converted from a liquid to a vapor by the process of evaporation. The liquid refrigerant entering the evaporator from the refrigerant flow control is suddenly under low pressure. This makes it vaporize or boil and absorb heat. The vapors then move on into the suction line. The evaporator is often referred to as a boiler, freezing unit, coil, and the low side. The temperature of the evaporator must be lower than that of the refrigeration space, which allows the heat in the refrigerated space to flow into the evaporator.

Evaporators are of two basic types, DRY and FLOODED, and are classified under four groups, according to their use, shape, size, application, etc. The four groups are: (1) type of surface (finned or prime); (2) operating condition (frosting, nonfrosting, and defrosting); (3) refrigerant control; and (4) circulation (natural and forced).

The DRY system was used long before the flooded system. In this system, a throttling device allows only the amount of refrigerant that is needed for a required temperature to enter the evaporator. There is only a small amount of liquid in the evaporator at all times, and it varies with load demands. The exact amount of liquid entering the evaporator may be controlled manually or automatically. The large industrial systems sometimes employ the manual control, while most other systems utilize the automatic control, containing a thermostatic expansion valve.

In the FLOODED systems, the evaporative element is filled (flooded) with the liquid refrigerant. This evaporator, under flooded conditions, becomes a boiling mass of liquid whose vapors are drawn off at the top by suction from the compressor through the trap or accumulator. The purpose of the accumulator is to separate the liquid that is entrained in the vapor carryover. The liquid is then returned to the evaporator for cycling again, thus allowing only saturated gas to enter the compressor.

The flooded system has an advantage of outstanding heat transmission, in that it employs the liquid wetted surface; whereas, the dry system uses the vapor wetted system. This is also the reason why smaller evaporators can be used for equal capacities. The flooded system is also more flexible in the distribution of refrigerant, particularly where a number of coils are connected to a common header to form a multipass arrangement. Flooded systems also have the advantage of employing several evaporators with only one accumulator and only one throttling device.

As was mentioned earlier, one of the classification groups of evaporators is the operating conditions: frosting, nonfrosting, and defrosting.

A FROSTING evaporator is used when the temperature never goes above 32° F in normal operation. The evaporators that are used in household refrigeration, frozen food storage, and low temperature refrigeration are normally in this category. This evaporator must be defrosted manually or automatically at certain intervals.

The NONFROSTING evaporators are used where temperatures remain above 32° F at all times. The nonfrosting evaporator is limited to high-temperature refrigeration, such as in air-conditioning, process cooling, the storage of bakery products, candy, vegetables, and dairy products.

In the DEFROSTING evaporators the temperature is below 32° F when the compressor is operating and above 32° F when the compressor stops. While the unit is operating the coils frosts up, but it defrosts itself when the unit stops. Because of the necessity of rapid heat flow during defrosting, forced convection evaporators are particularly adaptable to this type operation.

There are various evaporators in common use today. The BARE TUBE or PLATE evaporators are normally used where the box temperature is below 32° F and in liquid cooling. These evaporators may be defrosted by scraping off the accumulated ice. This reason makes them ideal for use in cold storage areas and other applications where it is impossible to raise the box temperature above the freezing temperature. Figure 3-26 illustrates a bare tube evaporator that is used as an overhead coil or in brine tanks.

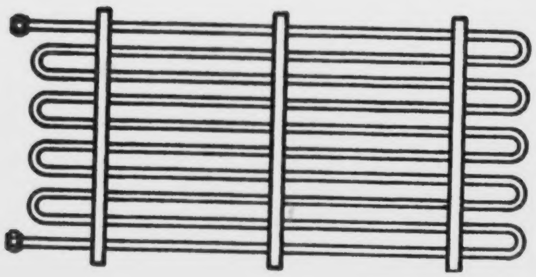

Fig 3-26. Bare tube evaporator.

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A PLATE evaporator is made by stamping out two plates to form tubes, and welding the plates together. Another method is to form a coil, cover it with plates, and weld the plates together. These evaporators are used in lockers, cold storage plants, refrigerated trucks, and for fast freezing of food. For fast freezing of foods, the evaporator serves as shelves and the food is placed directly on them. This arrangement allows for a fast heat transfer from the food to the evaporator.

FINNED evaporators are made of bare tubes covered with metal fins. These fins add surface area which aids in heat transfer. These evaporators are used in many applications. Formerly they were used only in air-conditioning and areas where the temperature did not go below 32° F. Today, with the aid of automatic defrost systems, these evaporators are used in applications where the temperatures goes down to 0° F, see figure 3-27.

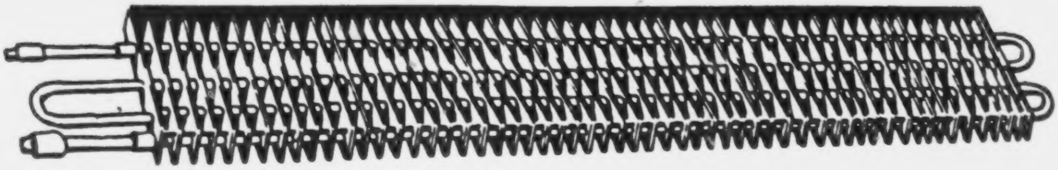

Fig 3-27. Finned evaporator.

Any type of evaporator with a mechanical means of moving the air is considered a forced air unit, called a FORCED CONVECTION evaporator. It normally consists of a finned coil with a fan to force the air through the coil. The finned coil and fan may be enclosed in a metal housing with openings for inlet and discharge air. Forced convection evaporators are very efficient, as they maintain an even temperature throughout the refrigerated space.

On occasion you will come into contact with special evaporators which are modifications of the fundamental types of evaporator coils. They are designed for special applications.

TANK-TYPE COOLERS consist of an evaporator coil submerged in a tank of liquid. This liquid is known as a secondary refrigerant. The secondary refrigerant may be either plain water or brine. If the required temperature is below 32° F, the secondary refrigerant must be a brine. Tank-type coolers are used almost universally in the production of ice. Milk coolers use a tank-type with plain water as a secondary refrigerant. This water acts as a "cold bank" device to prevent too great a temperature rise in the low side when warm milk is placed in the cooler.

The BAUDELOT or TUBULAR COOLER is used exclusively to cool liquids. It consists of a series of pipes or coils laid out in vertical arrangement (one over the other) through which the refrigerant passes, employing either the flooded or dry method of evaporation. There is a trough at the top provided with holes through which the liquid to be cooled flows and trickles over the coils in a cascade. The liquid is collected in another trough at the bottom of the coils. This type of cooler is easy to clean and maintain and is used extensively where aerating is a factor.

In the SHELL and COIL type cooler the dry expansion method is used. It may be used to cool any type liquid, but it most generally used in the common water cooler. This evaporator consists of a continuous single or double spiral coil with the refrigerant inlet and outlet located at the top. The refrigerant is inside the coil, while the liquid to be cooled is between the coil and the outside shell.

The SHELL and TUBE cooler is opposite the shell and coil cooler. It consists of a cylindrical shell in which a number of tubes are placed. The tubes run lengthwise and are connected by tube sheets at both ends that form an inlet and discharge header. This cooler is usually used to cool water or brine, and it can be operated under dry or flooded expansion conditions. When the flooded expansion is used, the liquid to be cooled (or the secondary refrigerant) flows through the tubes and the refrigerant surrounds the tubes. Usually these are reversed when the dry expansion is used.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of the evaporator in the refrigeration system.

2. Name the two basic types of evaporators.

   a.

   b.

3. What are the four groups in which evaporators are classified?

   a.

   b.

   c.

   d.

4 State the difference between the dry and flooded evaporator systems.

5. List the three advantages of the flooded system.

   a.

   b.

   c.

6. List the three operating conditions of evaporators.

   a.

   b.

   c.

7. Describe the following evaporators.

   a. Bare tube or plate -

   b. Finned tube -

   c. Forced convection -

8. Describe the following special types of evaporators.

   a. Tank-type cooler - ______________________________

   ____

   b. Baudelot cooler - ______________________________

   ____

   c. Shell and coil - ______________________________

   ____

   d. Shell and tube - ______________________________

   ____

Work Unit 3-5. ACCESSORIES

STATE THE PURPOSE, LOCATION, AND ADVANTAGES OF THE HEAT EXCHANGERS.

GIVE THE PURPOSE, LOCATION, AND PRINCIPLE OF OPERATION OF AN OIL SEPARATOR.

STATE THE PURPOSE OF DRIERS AND GIVE THE TYPES AND USES OF DESICCANTS.

STATE THE PURPOSE AND LOCATIONS OF VIBRATION ABSORBERS.

STATE THE PURPOSE AND LOCATIONS OF MUFFLERS.

Although compressors, condensers, evaporators etc., have been discussed as being main components in a refrigeration system, there are many refrigeration accessories that are as equally important. In fact, without most of these accessories, the efficiency of the system would be low, the ease of operation would not be a factor, and there would be more safety hazards. This work unit will discuss such accessories, such as heat exchangers, oil separator, and driers.

A HEAT EXCHANGER, whether used in refrigeration, heating, or any other application, is a device used for transferring heat. In the refrigeration industry, a heat exchanger (known as a liquid cooler) is used to transfer heat from the hot liquid line into the cool suction line. Figure 3-28 and 3-29 show a typical heat exchanger and its location. The suction vapor (at a low temperature) goes through the inside tube in one direction, and the hot liquid goes through the outside tube in the other direction. The counterflow effect of the hot liquid on cool vapor increases the heat transfer rate, and the hot liquid in the outside tubes keeps the heat exchanger from sweating. A heat exchanger provides several advantages:

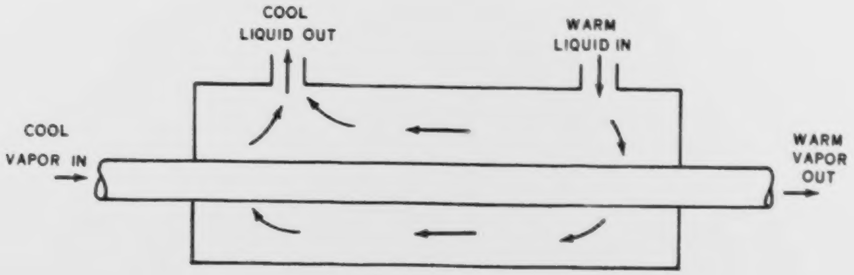

Fig 3-28. Heat exchanger.

- It minimizes flash gas. The reduction of flash vapor is very important. It results from the sudden change of a portion of the liquid to a vapor as the refrigerant passes through the refrigerant control. This action reduces volume capacity, increases the low side pressure drop, and reduces the amount of heat each pound of refrigerant can absorb as it evaporates. The flash vapor cools the remainder of the liquid to the evaporating temperature.
- Sweating or frosting of the suction line is minimized or eliminated.
- Flooding of liquid refrigerant to the compressor is minimized or eliminated.
- Liquid enters the expansion valve at a lower temperature. This advantage is very important in low temperature application. The hot liquid that comes from the receiver must have its temperature reduced in the evaporator before it can be evaporated. This means that the heat is being carried into the evaporator by the hot liquid. In passing through the expansion valve, part of the liquid vaporizes and takes up the sensible heat from the rest of the liquid, reducing its temperature to that of the evaporator. As an example, if one pound of 100° F liquid passed through the expansion valve into the evaporator with a temperature of 0° F, about 1/16 of a pound would be vaporized, reducing the 100° F liquid to 0° F. Therefore, there would be only 15/16 of a pound of liquid left to produce a refrigerating effect.
- It increases compressor efficiency. At air-conditioning temperatures, a heat exchanger will increase the volume of the suction gas enough to offset any advantage gained by reducing the amount of flash gas in the evaporator. This has caused many manufacturers to eliminate the use of heat exchangers in their air-conditioning systems. However, when you consider the following conditions, it becomes obvious that heat exchangers can be an advantage to all systems.

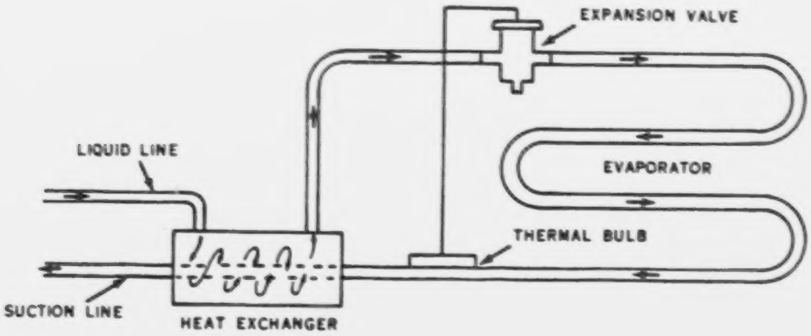

Fig 3-29. Location of heat exchanger.

All compressors must have an oil film on the sides of the cylinder to reduce friction between the cylinder and piston. If this film of oil is full of refrigerant each time the piston goes down, the refrigerant in the oil will evaporate in the cylinder. This reduces the amount of vapor the cylinder can remove from the evaporator. A heat exchanger will increase the temperatures of the suction gas. This, in turn, increases the temperature of the cylinder wall and the oil, which results in a thinner film of oil on the cylinder wall. The thin film of oil can hold very little refrigerant so the piston can remove more vapor from the cylinder each stroke.

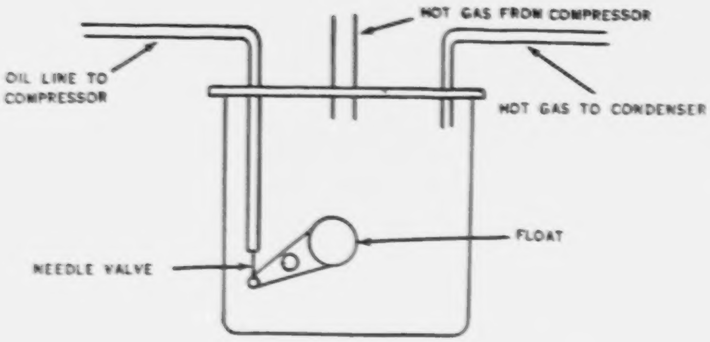

Fig 3-30. Oil separator.

OIL SEPARATORS, as the name implies, separate the oil from the refrigerant vapor. Compressors need lubrication, but there is a chance that too much oil will leave the compressor, since it pumps oil along with the vapor. Therefore, an oil separator is used. An oil separator consists of an enclosed steel cylinder with a float and a needle valve inside. It also has a gas line from the compressor, a gas line to the condenser, and an oil return line to the compressor crankcase, see figure 3-30.

As the hot compressed vapor and oil come from the compressor, they go into the separator. As this mixture arrives, the vapor slows down and the oil falls to the bottom of the separator. The hot vapor, free of oil deposits, then travels to the condenser, see figure 3-31. As the oil accumulates, its level activates a float assembly, which opens the needle valve. The high side pressure forces the oil to return to the low side of the compressor.

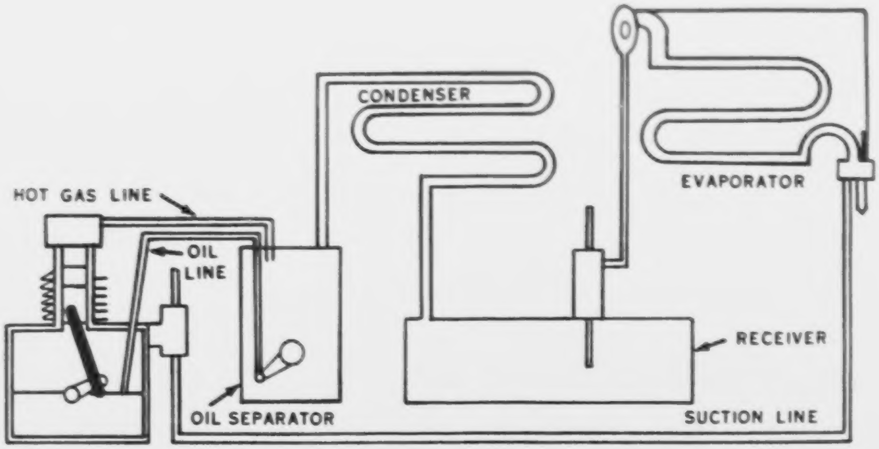

Fig 3-31. Location of oil separator.

The oil separator is insulated to prevent the refrigerant vapor from condensing in the separator and from being returned to the compressor as a liquid with the oil. Most expansion systems operating at temperatures above 0° F do not need an oil separator, but water coolers, low-temperature systems, and complex multiple installations operate much more efficiently with an oil separator.

Moisture must be eliminated during the manufacturing process, and its entrance must be guarded against in all fields of operation. If moisture does get into the system, you must remove it as soon as possible. The main sources of moisture are low-side leaks, contaminated oil, a contaminated refrigerant, and leakage in a water cooled condensing unit. Moisture may enter the system whenever it is open, such as during installation or when repairs are being made. Moisture in the system will cause one or more of the following undesirable effects:

- Freezing of the expansion valve/devices.
- Corrosion of metals.
- Chemical damage to the motor insulation or to other system components.
- A restricted or plugged filter.

Only clean dry refrigerant and oil must be allowed to circulate in the system. Since, despite all precautions, moisture does enter the systems, it must be reduced or eliminated as soon as possible. A DRIER is installed in the system. It normally consist of a brass, copper, or steel cylinder that holds filters and has its intervening space filled with a drying agent (desiccant), see figure 3-32. The drier is usually installed in the liquid line between the receiver and the expansion valve, thus getting it name - LIQUID LINE DRIER. Filter-driers mounted in the suction line are called SUCTION LINE DRIERS. Their main purpose is to prevent foreign particles, acids, sludge, and moisture from entering the compressor

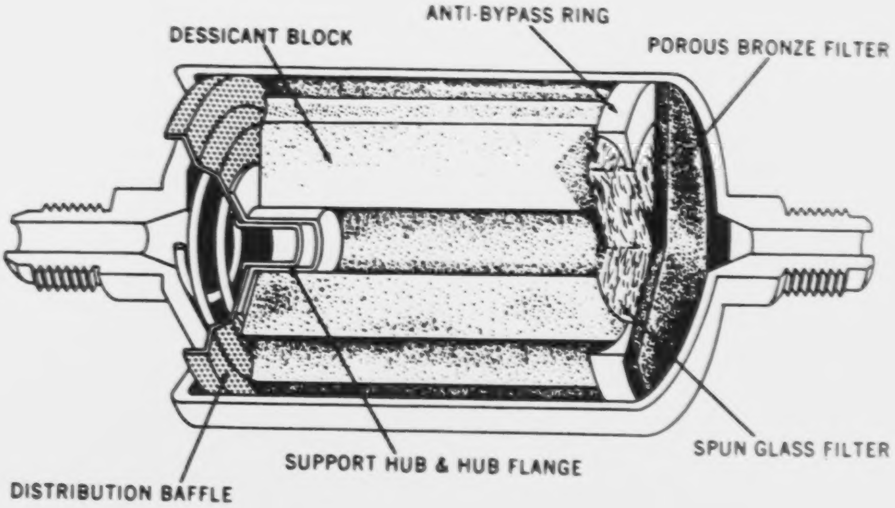

Fig 3-32. Filter-drier.

Desiccants, or drying agents, are of two types: ADSORPTION and ABSORPTION.

ADSORPTION DESICCANTS collect moisture mechanically by capillary attraction, whereby the liquid adheres to solid surfaces to form a thin film without apparent chemical change in either substance. Because there is no permanent adhesiveness between the moisture and the desiccant, the material of the desiccant can be reactivated and continually reused.

ABSORPTION DESICCANTS attracts moisture, and the two react to form another compound. This is a chemical relationship instead of a mechanical one. The moisture is absorbed by the drying agent, and it becomes an important ingredient of the newly formed compound. This type of desiccant can be installed in a new unit, but should not be left in the system for more than a few hours. Because of its ability to absorb moisture very rapidly, it removes the major portion of moisture in a new unit, and then an adsorption-type desiccant replaces it to continue the drying process.

Desiccants are rated according to the horsepower of the compressor motor. If no data is available, use 1 pound of desiccant for each pound of refrigerant in the system. CALCIUM CHLORIDE is a chemical desiccant that may be used with all refrigerants. It will not reduce the moisture content to a very low level, but is satisfactory for ordinary refrigeration systems. When calcium chloride absorbs excessive amounts of moisture, a highly corrosive liquid is formed which will escape and cause disastrous results. CALCIUM OXIDE is a cheap, but efficient desiccant. Its principal disadvantage is that it powders when it absorbs excessive amount of moisture, and this very fine powder may pass through the filter. CALCIUM SULPHATE is of a granular form. It has less dust than calcium oxide and, with the proper type of filter, it does not cause any difficulty. ALUMINUM OXIDE is of the absorption type, and it may be used with any refrigerant. SILICA-GEL is the most popular drying agent. It is slower than some of the other desiccants, and it may be left in the system indefinitely.

Vibration absorbers (eliminators) prevent the transmission of noise and vibration from the compressor through the refrigeration piping. Figure 3-33 shows a vibration absorber. They can be installed in both the suction and discharge lines. Vibration absorbers should be located as close as possible to the compressor or the condensing unit. The line connected to the end of the absorber opposite the source of vibration should be firmly anchored to the unit or to a wall. The fastening prevents the vibration from traveling along the pipe.

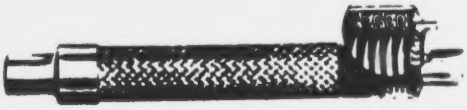

Fig 3-33. Vibration absorber.

Whenever the noise level is an important consideration mufflers are used. The purpose of a muffler is to dampen the pulses of gas created by the compressor. The muffler should be installed close to the compressor discharge. Mufflers are usually installed in a vertical position for efficient oil movement. Some are designed for fhorizontal installations. They have a dip tube which reaches the bottom to remove the accumulated oil. The velocity of the vapor that goes across the top of the tube creates a lower pressure in the dip tube; thus, the oil is siphoned up the tube and out the discharge of the muffler, as illustrated in figure 3-34.

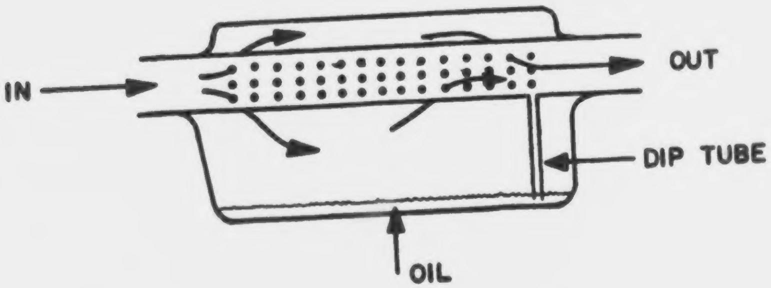

Fig 3-34. Muffler.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the purpose of a heat exchanger used in refrigeration applications?

2. Describe where in a refrigeration system the heat exchanger is located.

3. List the five advantages of using a heat exchanger.

   a.

   b.

   c.

   d.

   e.

4. What do oil separators do in a refrigeration system?

5. Describe how an oil separator works.

6. What is the purpose of driers?

7. The drier contains filters and either an ______________ or an ______________ type of desiccant.

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8. Give the use of the following types of desiccants.

   a. Calcium chloride - ______________________________

   b. Calcium oxide - ______________________________

   c. Calcium sulphate - ______________________________

   d. Aluminum oxide - ______________________________

   e. Silica gel - ______________________________

9. Explain the purpose of a vibration absorber.

   ____

   ____

10. Where is the most desirable location for vibration absorbers that are to be installed in the suction and discharge lines?

   ____

11. What is the purpose of a muffler?

   ____

   ____

12. In which refrigerant line are mufflers usually located?

   ____

SUMMARY REVIEW

During your study of this study unit, you learned the types of refrigeration systems and the major components within the refrigeration systems. You also learned how a mechanical refrigeration system is constructed. Finally, you learned the different types of compressors, condensers, receivers, evaporators, and accessories that you will encounter in the refrigeration field.

Answers to Study Unit #3 Exercises

Work Unit 3-1

1. a. Ice system
   b. Evaporative system
   c. Dry ice system
   d. Absorption system
   e. Vapor compression system
2. Vapor compression system
3. a. Compressor
   b. Condenser
   c. Metering device
   d. Evaporator

Work Unit 3-2

1. a. Single acting (vertical)

   b. Double acting (horizontal)

2. Closed crankcases for vertical type and open for horizontal type

3. a. They are made of close grain cast iron in either one or two pieces.

   b. The two piece type has the crankcase and cylinders cast separately, then bolted together

   c. The one piece type is cast in one block with a baseplate.

4. High speed compressors

5. a R

   b. C

   c. C

   d. R

   e. R

   f. C

   g. C

   h. R

6. The hermetic compressor is a completely welded unit, whereas the semi-hermetic is bolted so as to facilitate maintenance.

7. There is no shaft seal. This eliminates leakage.

8. a. Rotary

   b. Reciprocating

   c. Reciprocating

   d. Rotary

   e. Reciprocating

9. c - B

10. d - D

11. b - C

12. a - A

13. Check electrical power

14. A motor-stat analyzer or a multimeter

15. Charge and discharge it with its normal voltage, not to exceed 120 volts.

Work Unit 3-3

1. a. Desuperheating

   b. Condensing

   c. Subcooling

2. a. Surface area
   b. Type of cooling medium
   c. Temperature of cooling medium
   d. Material
   e. Condition of the surface
   f. Amount of cooling medium

3. The condenser disposes of the heat that is picked up from the evaporator.

4. a. Cooling load of the unit
   b. Weather factors of the locality

5. a They are normally of steel or copper tubing construction, with or without fins.
   b. This type consists of a shell of welded construction with a finned water coil. The refrigerant is between the shell and coil, and it holds the water.
   c. This type is constructed with two tubes, one inside the other. Water flows in one direction, and the refrigerant in the other.
   d. These types are made with steel shells with tube sheets at each end. Copper tubing connects both sheet ends.
   e. Water is sprayed directly over the condensing coils.

6. a. Vertical
   b. Horizontal

7. The shell and tube water-cooled condenser does not need a receiver because the bottom portion of the condenser is used a receiver.

8. To store surplus refrigerant

Work Unit 3-4

1. The evaporator converts liquid to vapor.

2. a. Dry
   b. Flooded

3. a. Type of surfaces
   b. Operating condition
   c. Refrigerant control
   d. Circulation

4. Basic difference is the amount of refrigerant. A small amount is used in the dry system and the evaporative element is filled in the flooded system.

5. a. Better heat transmission
   b. Smaller evaporator
   c. More flexible distribution of refrigerant

6. a. The frosting evaporator is used in units which have temperatures below 32º F It needs defrosting at certain intervals.

   b. The nonfrosting evaporator is used where temperatures remain above 32º.F. It needs no defrosting.

   c. The defrosting evaporator is used where temperatures go below 32º F when the compressor is operating and above 32º F when the compressor is stopped. This units defrost themselves when the compressor stops.

7. a. The bare tube evaporator is formed of coils or tubes and plates and is used for frozen foods. This type evaporator can serve as shelves for the fast freezing of foods.

   b. These are bare tubes covered with metal fins.

   c. Forced convection evaporators are any type of evaporators that uses a fan to force air through the tubes or coils.

8. a. The tank-type cooler has the evaporator coil submerged in a tank of liquid which acts as a secondary refrigerant.

   b. The baudelot cooler is a series of coils in a vertical tier arrangement. the liquid that is to be cooled flows over the coils in a cascade from a trough at the top to another trough at the bottom.

   c. The shell and coil cooler consists of a continuous coil in which the refrigerant flows. Liquid that is cooled flows between the coil and the shell.

   d. The shell and tube cooler consists of a number of tubes in which the liquid that is to be cooled flows. The refrigerant surrounds the tubes.

Work Unit 3-5

1. Its purpose is to transfer heat from the hot liquid line into the cool suction line.

2. It is located between the evaporator and the condenser.

3. a. It minimizes flash gas.

   b. Sweating or frosting of the suction is eliminated.

   c. Flooding of liquid refrigerant to the compressor is eliminated.

   d. Liquid enters the expansion valve at a lower temperature.

   e. It increases compressor efficiency.

4. They separate the oil from the refrigerant.

5. Compressed vapor and oil enter the separator from the compressor. Upon entering the separator the vapor slows down and the oil drops out and accumulates until its level causes a float assembly to open a needle valve. The high-side pressure then forces the oil back to the low-side of the compressor.

6. Driers are used to reduce or eliminate moisture from a refrigeration system.

7. Adsorption and or Absorption

8. a. Calcium chloride is used with all refrigerants.

   b. Calcium oxide is a cheap, efficient desiccant.

   c. Calcium sulphate is in granular form and may cause harm if not used with the proper filter.

    d. Aluminum oxide absorption type desiccant is used with all refrigerants.

    e. Silcia-gel is the most popular desiccant. It is slow but can be left in the system indefinitely.

9. Prevent the transmission of noise and vibration from the compressor.
10. As close as possible to the compressor or the condensing unit.
11. To dampen the pulses of gas created by the compressor.
12. Discharge line.

STUDY UNIT 4

REFRIGERATION CONTROLS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY VARIOUS REFRIGERATION CONTROLS THAT PROVIDE EASY, SAFE OPERATION OF REFRIGERATION SYSTEMS. YOU WILL IDENTIFY SOME OF THE OPERATING AND MAINTENANCE FEATURES OF THESE CONTROLS, PLUS THE MOTOR AND SAFETY CONTROLS AND THEIR MAINTENANCE TASKS. ALSO, YOU WILL IDENTIFY THE DIFFERENT MOTORS THAT ARE USED IN MODERN REFRIGERATION SYSTEMS.

Your BRAIN is a control system. It controls your movements and it responds to various situations. Have you ever touched something hot? If you have, you undoubtedly released it immediately, didn't you? The control system of a refrigeration or air conditioner acts like a brain. It senses a change and responds with a corrective action.

The basic refrigeration control is a device that starts/stops, regulates and/or protects the refrigeration cycle and its components. Though it may take almost any form and may be operated by different forces such as temperature or pressure, the function of the control is always the same.

In this study unit, some of the refrigerant controls that provide easy, safe operation of the refrigeration system will be covered. Also, some of the operating and maintenance features of these controls, including the motor and safety controls and their maintenance tasks will be presented to you.

Work Unit 4-1. CONTROLS

STATE WHAT A SIGHT GLASS IS AND HOW YOU USE IT.

SPECIFY THE TYPES AND PURPOSE OF PRESSURE RELIEF VALVES.

DESCRIBE THE TYPES AND USES OF THE WATER REGULATING VALVES.

DISTINGUISH BETWEEN THE CHARACTERISTICS AND USES OF SUCTION PRESSURE CONTROL VALVES AND THOSE OF TWO TEMPERATURE VALVES.

IDENTIFY THE PURPOSE AND TYPES OF CHECK VALVES USED IN A REFRIGERATION SYSTEM.

STATE THE PURPOSE AND OPERATING PRINCIPLE OF THE DEFROST TIMER.

DESCRIBE THE TYPES AND PRINCIPLES OF OPERATION OF THE SOLENOIDS.

A SIGHT GLASS is installed in the liquid line of a refrigeration system to visually determine if the system has enough refrigerant. The sight glass should be installed as close as possible to the receiver, but far enough downstream to avoid any disturbance resulting from valve action. When the system has a low charge, vapor bubbles will appear in the sight glass. This indicates to the serviceman that the system needs more refrigerant. Occasionally, when liquid lines are quite long, an additional sight glass in the front side of the refrigerant control shows the stream of refrigerant reaching the control. Bubbles at this point indicate that the liquid is flashing because of an excessive pressure drop. These bubbles can only be eliminated by reducing the pressure drop or by further subcooling the liquid refrigerant.

PRESSURE RELIEF VALVES are valves designed to relieve excessive, dangerous pressure from a refrigeration system. They are normally installed on the liquid receiver, but on some units that you may come into contact with, they can also be located on the water-cooled condenser. The National Refrigeration Code sets down requirements for the type and number of valves used, where they are to be located, and on what units.

There are three main types of relief valves. One type is the FUSIBLE PLUG. This is a pipe plug which has been drilled out and filled with a metal alloy that will melt at a predetermined temperature, which depends on the pressure-temperature relationship of the refrigerant used in the system.

Another type of relief valve is the RUPTURED-DISK. This device looks the same as the fusible plug, but it has a thin metal (usually silver) disk inside. This disk bursts when the pressure in the system reaches an abnormal, dangerous level. The third design is the SPRING-LOADED SAFETY VALVE. Unlike the other types, this valve can be permanently used. It has the ability to close and reseal itself after it has relieved the dangerous pressure in the system. This valve is adjustable, but once a pressure is set, it is sealed to prevent tampering. If the seal is broken, the valve must be replaced with a properly adjusted one. Pressure relief valves are designed to close when the pressure drops to a safe limit, which is normally 10 to 20 percent below their opening pressure.

Note: MANUAL HAND VALVES MUST NEVER BE INSTALLED BETWEEN THE SYSTEM AND ANY TYPE OF RELIEF VALVE.

WATER REGULATING VALVES are essentially what their name implies. They turn the water on or off and regulate its flow. Three types of valves are used to regulate this flow of water within a refrigeration system: ELECTRIC, PRESSURE, and THERMOSTATIC.

The ELECTRIC WATER VALVE is located between the water supply and the condensing unit, normally on the condensers' base. It works simultaneously with the motor. Electric valves usually operate on 120 volts and use from 6 to 10 watts of power.

A PRESSURE-OPERATED VALVE is probably the most popular. It uses a bellows to operate the valve. When the pressure in the condenser rises, the bellows expands and, through a variaty of mechanisms, the valve portion moves. As water flows into the condenser, it cools the compressed vapor, reduces the pressure and, in turn, causes the bellows to contract. This causes the operating mechanism to close the valve. These valves may be set to a predetermined pressure by adjusting a heavy spring which presses against the bellows. The pressure depends on the temperature of the water and the particular refrigerant that is used.

The THERMOSTATIC WATER VALVE is about the same as the pressure-operated valve, except that it uses a thermostatic element which is connected to a bellows. This valve then works on the temperature of the exhaust water. The thermostatic element is charged with a volatile substance, and is located in the condenser line. Temperature change causes the liquid to expand or contract, and thus causing the valve to open or close.

Various systems use SUCTION PRESSURE VALVES to maintain a certain pressure in the evaporator. This pressure has no bearing on the low side of the compressor or the cooling demand. Generally a bellows or diaphragm in the valve responds only to the pressure that is in the evaporator. When the evaporator pressure reaches approximately 30 psi, the bellows (diaphragm) opens the valve. When the pressure falls below 30 psi, the valve closes. There are two basic types of suction pressure valves: a SUCTION THROTTLING VALVE and an EVAPORATOR PRESSURE REGULATOR, see figure 4-1. The main purpose of a suction pressure control valve is to keep the temperature of the evaporator above freezing, so that the moisture condensing on the evaporator will not freeze as the air flows through it.

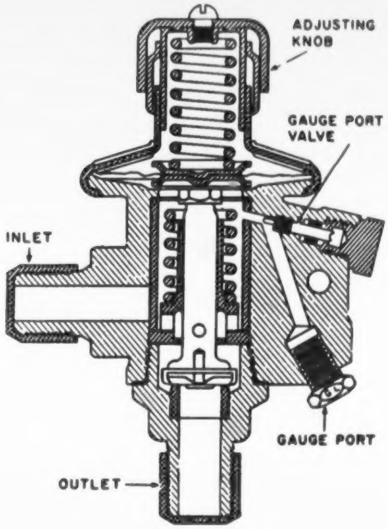

ADJUSTING KNOB
GAUGE PORT VALVE
INLET
GAUGE PORT
OUTLET

Fig 4-1. Suction-pressure valve.

TWO-TEMPERATURE VALVES like the one in figure 4-2 are generally used on multiple installations, where it is important to maintain different temperature in different evaporators connected to the same system. A valve of this type (sometimes called a constant pressure valve, or a pressure reducer) is mounted into the warmest evaporator suction line. This maintains the pressure of the warmest evaporator, and prevents it from falling below a safe setting.

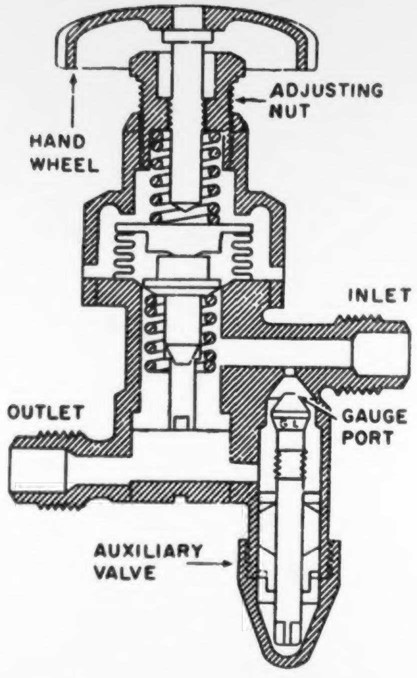


Fig 4-2. Two-temperature valve.

These valves are also used to insure a constant low-side pressure. They are usually constructed of a bellows or diaphragm, a needle, and its seat. These are set in such a manner that the bellows is operated by the pressure in the warmest evaporator. As the compressor pumps down the low side to the desired pressure, the valve is activated by the bellows and shuts off. Thus, the pressure in the warmest evaporator is prevented from going below the desired pressure. When the pressure in the evaporator again begins to build up (from vaporizing the refrigerant) the bellows activates the valve. As the valve opens the vapor passes on to the compressor.

There are two general types of two-temperature valves: PRESSURE-OPERATED (metering and snap-action) and TEMPERATURE-OPERATED (sensing bulb, bellows, thermostat, and solenoid).

CHECK VALVES are used in refrigeration systems, as in all other systems, to prevent the reversal of flow. they are used in two-temperature installations, to prevent vapor passage during the off cycle, and in defrost systems. Check valves will remain open when fluids and/or vapors are flowing in the right direction during normal operation, but will close automatically when changing conditions within the refrigeration system tend to force a reversal of the flow.

There are two types of check valves: the SWING-CHECK (see fig 4-3) and the LIFT-CHECK (see fig 4-4). The swing-check valve has a hinged disk that seats against the tilted bridge wall opening of the valve body (see fig 4-3). This disk swings freely on its hinge pin from a fully closed position to one parallel with the flow. The fluid or vapor in the line enters below the disk. Pressure overcomes the weight of the disk and raises it, permitting a continuous flow. If the flow is reversed or back-pressure builds up, this pressure is exerted against the disk, forcing it to close and stop the flow.

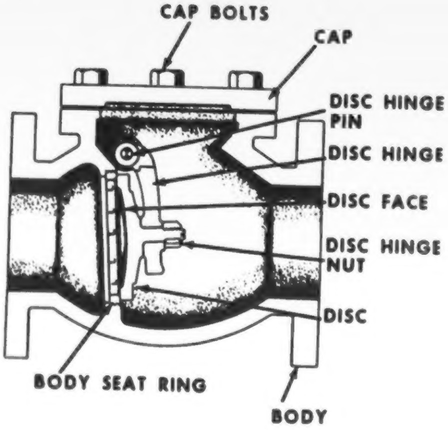


Fig 4-3. Swing-check valve.

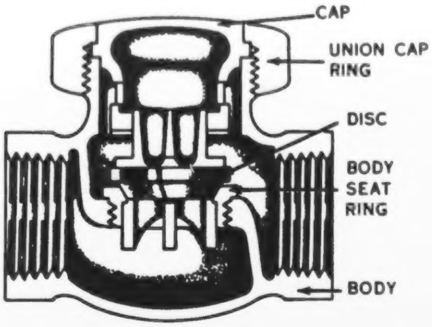


Fig 4-4. Lift-check valve.

The lift-check valve's disk seats on a horizontal bridge wall in the valve body (see fig 4-4). The disk is raised from its seat by the pressure of the fluid flow and moves vertically to open. The valve is closed by back-flow, or by gravity when there is no flow.

Most automatic defrost systems use a DEFROST TIMER to start the defrost cycle. The basic component is an electric, self-starting clock. The mechanism within the clock operates a cam which operates various switches. Some of these clocks are connected straight to an electric power source, and will defrost the system at scheduled intervals. This is necessary to keep the system working well. Every evaporator has its own defrosting requirements such as at each cycle, or every few hours, or once a day. The cams can be adjusted to correspond to the individual evaporators' requirements.

Some of the timers are connected to electrical power in parallel with the motor. They measure the running time of the condensing unit, and the defrost cycle is activated after a scheduled number of hours running time. Some timers that depend on the system energize a solenoid bypass valve to stop the fan motor, start an auxiliary electric heater element, and operate the compressor. These may also prevent the normal cycle from starting until the low-side pressure is at a normal level.

Another automatic timer starts the defrost cycle while the temperature bulb is returning the unit to a normal operation cycle, after the evaporator reaches a temperature above 32° F. Still another timer starts defrost action and also a pressure control (low-pressure side) that returns the system to normal operation. This timer can be used with either air defrost action, or electrical heat action.

SOLENOID VALVES in refrigeration systems automatically close off or open a circuit to produce the desired refrigerating effect. It is simply an electromagnetic device with a moveable core (center) and an armature. This armature (made of iron alloy) is attached to a moveable needle. The basic principle of a solenoid is illustrated in figure 4-5. When the solenoid coil is energized, the magnetic armature, or plunger, moves upward toward the center of the coil, thus opening the valve. When the circuit opens, the coil de-energizes and the spring and the weight of the plunger forces the valve against the valve seat, thereby closing the valve.

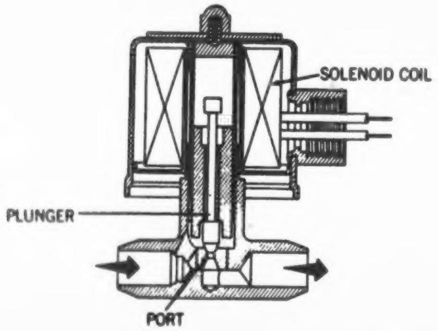


Fig 4-5. Solenoid (direct-acting).

There are two basic types for solenoid valves that you may find in use: the DIRECT-ACTING (fig 4-5) and the PILOT-OPERATED (fig 4-6). In the direct-acting type, the pull of the coil opens the valve port directly by lifting the pin out of the valve seat. Since this valve depends solely on the power of the solenoid coil for operation, its port size, for a given pressure differential, is limited by the coil size.

Large solenoid valves are usually of the pilot-operated design. With this type, the solenoid plunger does not open the main port directly, but merely opens the pilot port (A), refer to figure 4-6. Pressure trapped on top of the piston (B) is released through the pilot port, thus creating a pressure imbalance across the piston (B). Because the pressure underneath is now greater than the one above, the piston moves upward. This opens the main port (C). To close port (C), the coil is de-energized, causing the plunger to drop and close the pilot port (A). Now the pressure above and below piston (B) equalizes. Piston (B) will close the main port (C). The pressure difference across the valve, acting on the area of the valve seat, holds the piston closed tightly.

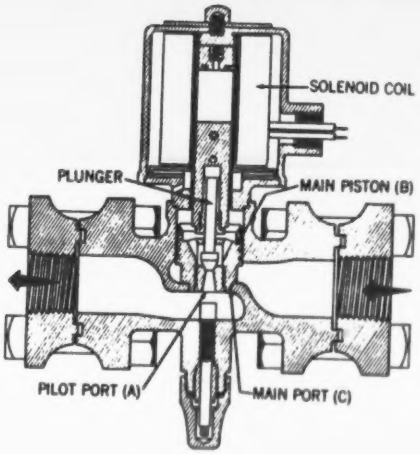


Fig 4-6. Solenoid (pilot-operated).

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of the sight glass in a refrigeration system.

2. In a refrigeration system, where should the sight glass placed?

3. If trouble is indicated by the sight glass, identify the three ways by which it may be eliminated.
   a.
   b.
   c.

4. State the purpose of pressure relief valves.

5. State when will the following relief valves operate.
   a. Fusible plug -
   b. Ruptured disk -
   c. Spring-loaded safety valve -

6. What are water valves used for in a refrigeration system?

7. Where are the water valves normally located in the system?

____

8. Identify the three types of water regulating valves.

a. ______________________________

b. ______________________________

c. ______________________________

9. State whether each item below refers to a suction pressure control valve or a two-temperature valve. Place your answer in the space provided.

a. It is activated at a 30 psi evaporative pressure.

____

b. Referred to as a pressure reducer.

____

c. It keeps the evaporator temperature above freezing.

____

d. Insures a constant low-side pressure.

____

e. A desired pressure is kept in the warmest evaporator.

____

f. It uses a sensing bulb and a bellows.

____

10. What is the purpose of check valves?

____

11. What is the difference between the two types of check valves?

____

____

12. State the purpose of a defrost timer.

____

____

13. Describe the operating characteristics of a defrost timer.

____

____

14. How does a solenoid valve work?

____

____

15. Identify the two types of solenoid valves that you may work with.

a. ____

b. ____

Work Unit 4-2. EXPANSION VALVES AND CAPILLARY TUBES.

LIST THE CONSTRUCTION FEATURES AND GIVE THE OPERATING PRINCIPLES OF AUTOMATIC EXPANSION VALVES.

EXPLAIN THE AUTOMATIC EXPANSION VALVE'S OPERATION DURING AN INCREASE IN HIGH SIDE PRESSURE AND A FLUCTUATION IN HEAT LOAD.

DESCRIBE THE CONSTRUCTION FEATURES AND OPERATING PRINCIPLES OF THE THERMOSTATIC EXPANSION VALVE.

STATE WHERE THE THERMAL BULB SHOULD BE LOCATED UNDER SPECIFIC CONDITIONS.

COMPARE THE VARIOUS REFRIGERANT CHARGES OF THE THERMAL BULB.

BRIEFLY DESCRIBE A CAPILLARY TUBE.

STATE WHEN AND HOW TO REPLACE A CAPILLARY TUBE.

EXPANSION VALVES, in the early days of mechanical refrigeration, were manually operated. This type may still be used in some systems, but most of them have been replaced with modern expansion valves.

This valve was developed to control the flow of liquid refrigerant to the evaporator automatically by maintaining a constant evaporator pressure. The AUTOMATIC EXPANSION VALVE is essentially a PRESSURE-REGULATING VALVE (sometimes called a constant pressure valve). It is designed to maintain a constant pressure in the evaporator, regardless of changes in heat loads or high side pressure.

The AUTOMATIC EXPANSION VALVE (AEV) (fig 4-7) consists of a closing spring (P_3) which pushes upward to close the valve, a needle and needle seat, drive pins which push on the needle carrier to open the valve, a diaphragm, an opening spring (P_1), an adjusting screw, and a vent hole to allow atmospheric pressure (P_4) to press downward on the diaphragm.

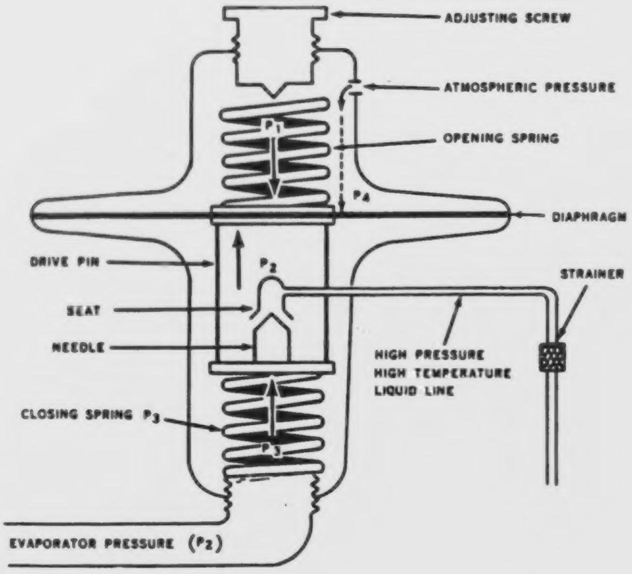

ADJUSTING SCREW
ATMOSPHERIC PRESSURE
OPENING SPRING
P1
P4
DIAPHRAGM
DRIVE PIN
P2
STRAINER
SEAT
NEEDLE
HIGH PRESSURE
HIGH TEMPERATURE
LIQUID LINE
CLOSING SPRING P3
P3
EVAPORATOR PRESSURE (P2)

Fig 4-7. Automatic expansion valve.

In modern automatic expansion valves, the area above the diaphragm is filled with relatively dry air or nitrogen gas. This is done to keep out moist air, which might form ice and prevent the spring from opening. It also acts as a cushion and affects the diaphragm in the same way as atmospheric pressure.

High-pressure, high-temperature liquid refrigerant from the liquid line changes to a low-temperature liquid at the valve seat (see fig 4-7). Atmospheric pressure (P_4) pushes downward to open the valve. Closing spring pressure (P_3) pushes upward to close the valve. These pressures, being equal and opposite, cancel out each other and need not be considered. Therefore, the only pressures to consider are opening spring pressure (P_1) and evaporator pressure (P_2) which closes the valve. Figure 4-8 and 4-9 illustrate this. The evaporating pressure is varied by changing the pressure on the opening spring with the adjusting screw. Turning the screw clockwise increase the evaporator pressure; counterclockwise decreases the evaporator pressure.

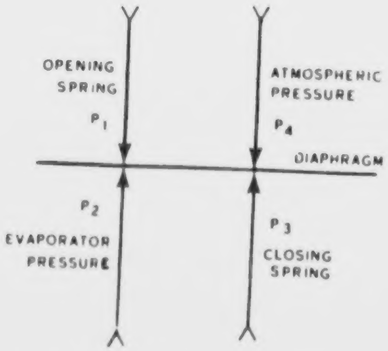


Fig 4-8. Pressure on automatic expansion valve diaphragm.

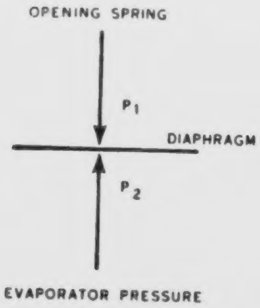


Fig 4-9. Operating pressure on automatic expansion valve.

During normal operation, the valve is approximately three quaters open. A slight movement of the needle is necessary to regulate the refrigerant flow and to keep the evaporator pressure almost constant. When the compressor stops, the valve remains open for a moment. During this time the evaporator pressure overcomes the opening spring pressure and thus closes the valve. As the evaporator warms up during the off cycle, its pressure rises in accordance with the pressure-enthalpy (P-E) chart and may be several psi above normal operating pressure. The higher the pressure the tighter the valve closes.

When the compressor starts, the valve does not open immediately. This factor is an important advantage, because the compressor motor is not overloaded on start-ups. The valve will not open until the compressor reduces the evaporator pressure to the pressure setting of the valve. As the compressor reduces the evaporator pressure (P_2), it becomes less than the opening spring pressure (P_1) (see fig 4-10). This action opens the valve. It opens to such a position when the opening spring pressure and the evaporator pressure are in balance.

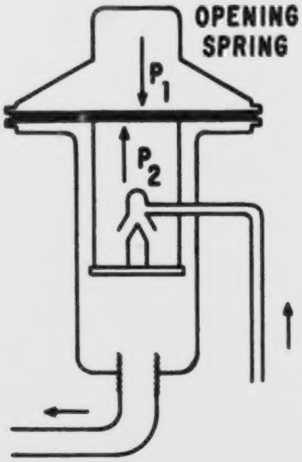


Fig 4-10. Opening spring pressure.

When the condensing temperature increases, the high-side pressure also increases. This increase in pressure will force more refrigerant through the valve and thus increase the evaporator pressure. The valve becomes unbalanced, causing it to close slightly and reduce the refrigerant flow and evaporator pressure, but the evaporator pressure will return to the valve setting. The valve should maintain a fairly constant pressure in the evaporator. It should not fluctuate more than 1/4 psi during operation.

Lets consider now a system containing refrigerant R-12; the evaporator pressure is at 21 psi and its temperature is at 20° F. When a heat load is added to the system, it causes the refrigerant to vaporize faster. This causes a rise in evaporator pressure and point V (see fig 4-11) moves to the right. This increase in evaporator pressure tends to close the valve allowing less refrigerant to enter the evaporator; therefore, the evaporator is less active.

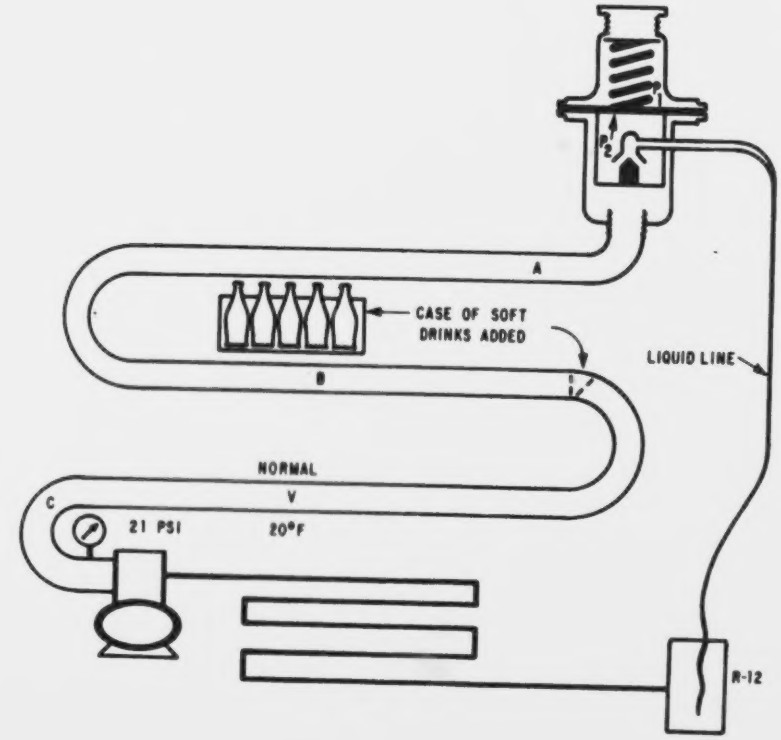


Fig 4-11. Automatic expansion valve during heat load.

A decrease in heat load would have an opposite effect. When the evaporator pressure decreases, it tends to open the valve more. Point V would move to the left, flooding the evaporator. Under this condition, liquid refrigerant could enter the compressor. This is a major disadvantage of the automatic expansion valve. It starves the evaporator when the heat load is increased and floods the evaporator when the load is decreased.

The THERMOSTATIC EXPANSION VALVE (TEV) is a further development and improvement of the automatic expansion valve, and it was first introduced to the refrigeration industry in the late 1920s. Its purpose is to regulate the flow of refrigerant entering the evaporator, maintaining a fully active evaporator regardless of the heat load and pressure changes. It does this by maintaining a constant degree of superheat. (SUPERHEAT is heat that is added to a gas or vapor above its saturation temperature.)

The thermostatic expansion valve consists of the following parts: a thermal bulb, capillary, diaphragm, push rods, valve seat and needle, spring, and an adjusting screw (see fig 4-12). The thermal bulb, which is a power element, contains a charge of refrigerant. Pressure developed by the charge is transmitted through the capillary to the diaphragm. The type of charge in the bulb depends on the application. Charges are classified into four main groups: (1) gas-charged, (2) liquid-charged, (3) cross-charged, and (4) special-charged.

We began by saying that the thermostatic expansion valve maintains a fully active evaporator, regardless of the heat load and pressure changes. In actuality this is not quite true. A small portion of the evaporator is used for superheating the vapor, because the change in superheat controls the valve.

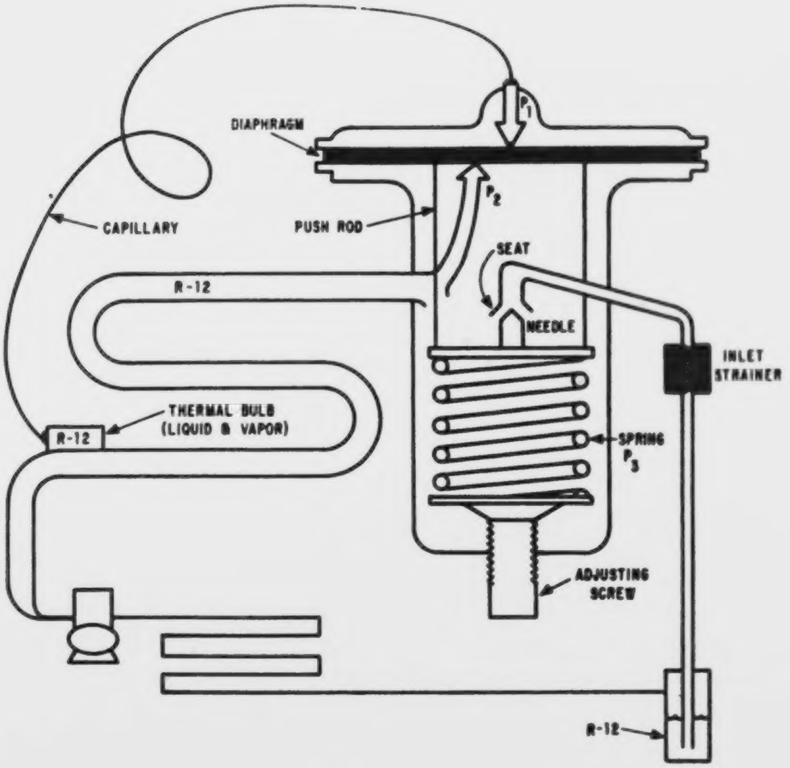

DIAPHRAGM
P_1
P_2
CAPILLARY
PUSH ROD
SEAT
R-12
NEEDLE
INLET STRAINER
THERMAL BULB (LIQUID & VAPOR)
R-12
SPRING P_3
ADJUSTING SCREW
R-12

Fig 4-12. Thermostatic expansion valve.

Referring to figure 4-8 and 4-13, observe the similarity of the thermostatic and automatic expansion valves. Note that the opening spring (P_1) has been replaced by bulb pressure (P_1). Evaporator pressure (P_2) is the same for both valves. In the automatic expansion valve, the closing spring pressure and the atmospheric pressure are the same, so they are not considered. In the thermostatic expansion valve, the closing spring (superheat spring) aids the evaporator pressure in closing the valve.

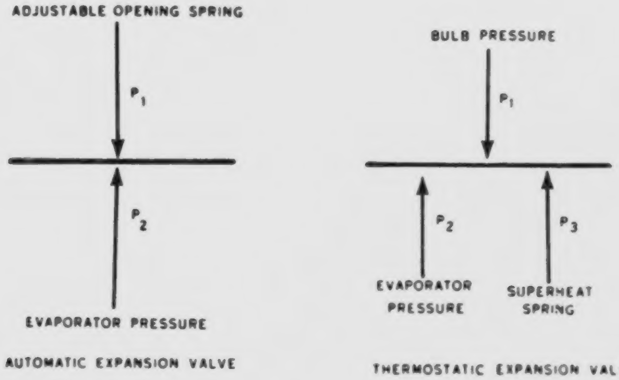

ADJUSTABLE OPENING SPRING
P_1
P_2
EVAPORATOR PRESSURE
AUTOMATIC EXPANSION VALVE
BULB PRESSURE
P_1
P_2
P_3
EVAPORATOR PRESSURE
SUPERHEAT SPRING
THERMOSTATIC EXPANSION VALVE

Fig 4-13. Comparison of pressures on expansion valve diaphragms.

The operating pressures of both types of expansion valves are compared in figure 4-13. Both valves have P_1 and P_2, but the thermostatic valve has an additional pressure P_3, which helps close the valve. In the thermostatic expansion valve, P_1 is equal to P_2, thus balancing the valve. In the thermostatic valve, it is $P_1 = P_2 + P_3$, meaning that the evaporator pressure plus superheat spring pressure is equal to bulb pressure when the valve is in balance.

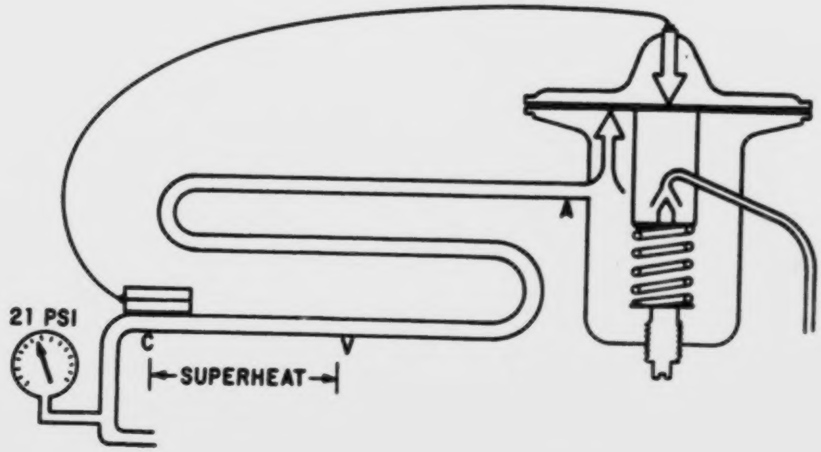


Fig 4-14. Normal operating system with R-12 refrigerant.

Now look at figure 4-14, both the system and the valve contain R-12. Point V is the point of complete vaporization. The temperature of the liquid and vapor from point V to point A is the same. The location of point V is not too important, but the temperature at point V is. The temperature at point V can be known by converting suction pressure to temperature. In figure 4-14, the suction pressure, as can be seen by the gage, is 21 psi. The temperature from A to V is 20° F. Now, lets find the amount of superheat. Attach the bulb of a superheat thermometer at point C (see fig 4-15). This is 30° F. Convert the suction pressure to temperature: 21 psi = 20° F, which is the temperature at point V. Subtract the temperature at point C: 30° - 20° F = 10° F superheat.

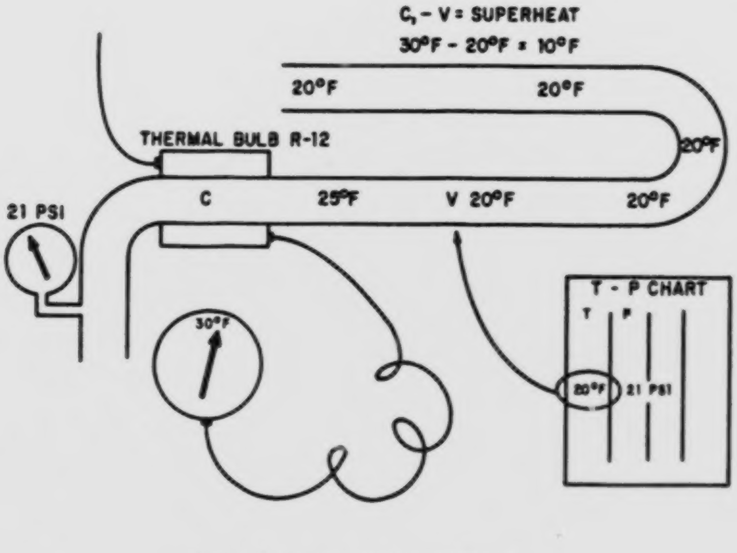


Fig 4-15. To find superheat.

The thermal bulb should be clamped to a horizontal suction line near the evaporator outlet. Clean the suction line throughly before clamping the remote bulb in place. On suction lines under 7/8 inch OD, install the remote bulb on top of the line, and on 7/8 inch up to 2-1/8 inches OD, install the bulb at the position of 4 or 8 o'clock (see fig 4-16). On lines 2-1/8 inches and larger, place the bulb inside the suction line.

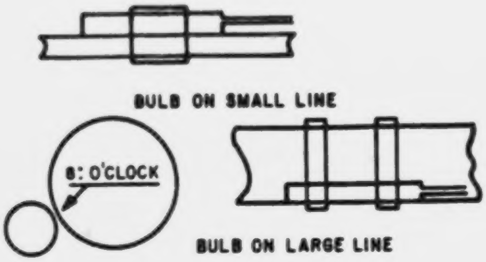


Fig 4-16. External bulb on suction line.

The thermal bulb must never be installed where the suction line is trapped as shown in figure 4-17. A collection of liquid refrigerant at the bulb's location will cause irregular operation of the expansion valve. Large fluctuation in pressure and superheat of the suction gas usually results from trapped liquid at the bulb's location. Even on properly designed suction lines, it is sometimes necessary to move the bulb a few inches either way from the original location to obtain the best valve action. ALWAYS locate the bulb on the evaporator side of the heat exchanger.

When the remote bulb is outside the refrigerated space, both the bulb and the suction line must be well insulated from the surrounding ambient temperature. The insulation must extend at least 1 foot or more on both sides of the bulb. When the thermal bulb is inside the refrigerated space, the temperature difference between the evaporator and space is not usually large enough to adversely affect expansion valve operation.

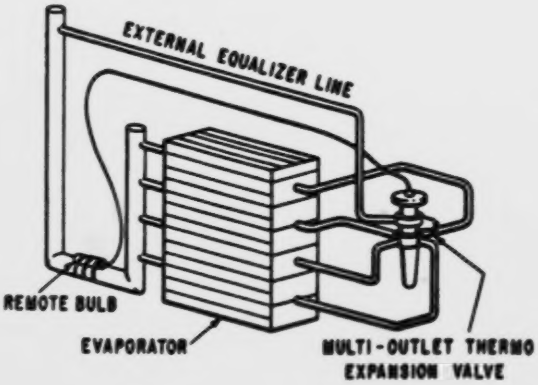


Fig 4-17. Remote bulb location showing trap.

Figure 4-17 illustrates one of the more common incorrect remote bulb applications that may cause valve "hunting" and "flood back." Liquid may be trapped in the suction line at the evaporator outlet, causing the loss of operating superheat and resulting in irregular valve operation due to the alternate drying and filling of the trap. Figure 4-18 shows the piping corrected and the trap removed. This allows for free drainage away from the remote bulb location. "Hunting" of the expansion valve can be defined as the alternate over feeding and starving of the evaporator. It is recognized by extreme cycle changes in both the superheat and the suction pressure. Figure 4-19 illustrates the proper remote bulb location to keep trapped oil or liquid from affecting the expansion valves' operation when the suction line must rise at the evaporators' outlet.

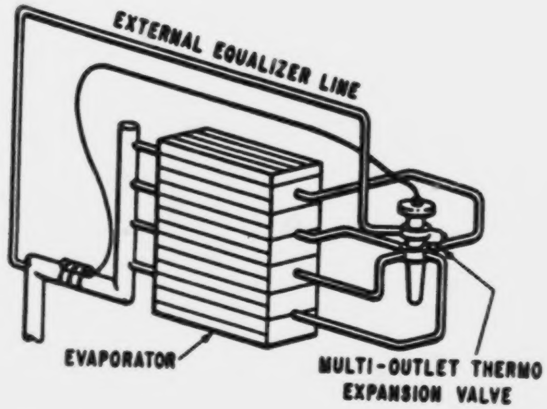


Fig 4-18. Remote bulb location showing free draining.

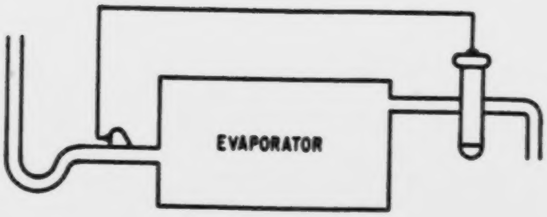


Fig 4-19. Recommended remote bulb location and schematic piping for rising suction line.

Thermostatic expansion valves require a different type of refrigerant charge in the thermal bulb for each temperature range, see figure 4-20. The dividing line between the different charges is not clear cut. A gas-charge valve may be used with a temperature as low as 26° F without too much loss in efficiency. Also, a cross-charged valve may be used where the temperature reaches 35° to 37° F.

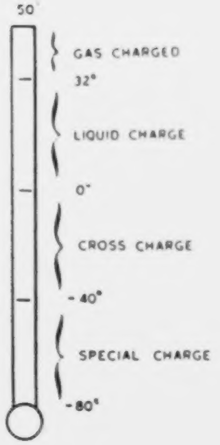


Fig 4-20. Temperature ranges of valves.

The GAS-CHARGED VALVE BULB contains the same type of refrigerant as used in the system. The amount of refrigerant is limited so that at a predetermined temperature all refrigerant has vaporized. This limits the amount of pressure that can be exerted by the bulb and is called M.O.P. (Maximum Operating Pressure). Any time the evaporator pressure becomes greater than the M.O.P., the valve closes and remains closed until the evaporator pressure is reduced below the M.O.P. The main advantages of the gas-charged valve are: (1) it prevents flooding of the evaporator during the OFF cycle; (2) it allows rapid pulldown; and (3) it prevents overloading of the compressor motor. Its main disadvantages are that it cannot be used on low temperature applications, and that the body of the valve must not become colder than the bulb. If it does, the charge will condense in the body of the valve, and the control by the bulb will be lost.

The CROSS-CHARGED VALVES use a different fluid in the power element than the refrigerant used in the system. The cross-charged valve is especially useful in low temperature applications. The cross-charged valve creates a high initial superheat which tends to prevent flood back and motor overload during the initial pulldown. At high evaporator temperatures, the valve maintains a very high superheat; as the evaporator temperature lowers, the superheat gradually returns to normal. When the compressor stops, the valve closes quickly to prevent flooding of the evaporator.

Ultra low temperature refrigeration (-40° F and less) uses a SPECIAL-CHARGED VALVE. Each application requires its own specially engineered valve. Before changing the type or size of these valves, consult the valve's manufacturer.

LIQUID-CHARGED VALVES contain the same refrigerant as the system does. This type of valve operates on the principle of expansion or contraction of a liquid as it changes temperature. The advantage of this type is that the valve will control refrigerant flow even if the valve body is colder than the thermal bulb. One main disadvantage is that, during the initial pulldown when the compressor starts, the evaporator temperature is immediately reduced. Since the thermal bulb is not cooled as fast as the evaporator, the pressure difference across the diaphragm tends to open the valve completely with a possibility of floodback. It also imposes a maximum load on the motor during pulldown, and it delays suction pressure pulldown. During the OFF cycle, the bulb may warm up enough to open the valve. This will flood the evaporator and cause floodback on start-up.

Liquid-charged valves must contain some type of pressure limiting device, so they cost more than gas-charged or cross-charged valves. Nevertheless, if the valve body must be located in an area that is colder than the thermal bulb, you must use a liquid-charged valve.

The pressure limiting device may consist of a gas-charged pressure cartridge or collapsible link installed between the diaphragm and the push rods that open the needle valve (see fig 4-21). As long as the evaporator pressure is below the pressure charge of the cartridge, the cartridge acts as a solid piece, transmitting the power element pressure to the push rods. When the pressure in the evaporator exceeds the cartridge pressure, the cartridge collapses, allowing the spring to close the valve. The valve will remain closed until the evaporator pressure has been reduced below that in the cartridge.

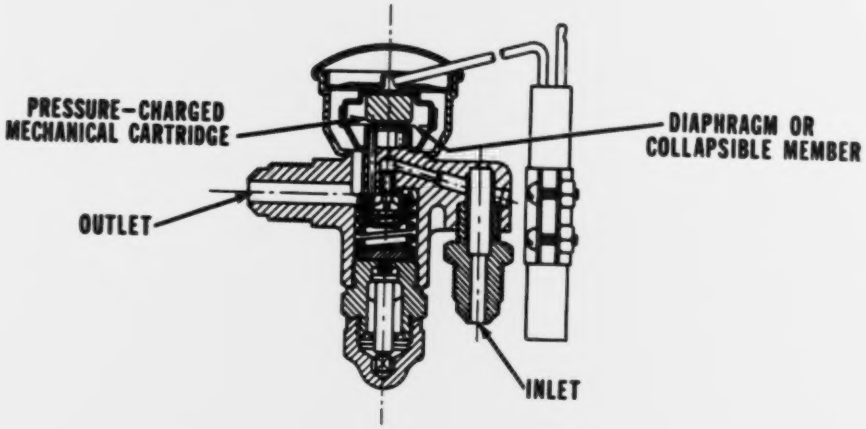

PRESSURE-CHARGED MECHANICAL CARTRIDGE
DIAPHRAGM OR COLLAPSIBLE MEMBER
OUTLET
INLET

Fig 4-21. Pressure limiting device.

The CAPILLARY TUBE, located between the condenser and evaporator (see fig 4-22), is used on practically all small applications such as domestic refrigerators, home freezers, room air conditioners, drink fountains, and some central air conditioning systems. It is the simplest of all refrigerant controls; it consists of a length of small diameter seamless copper tubing. The diameter and length depend upon the refrigerant, capacity and application. When a liquid is forced through a pipe or small tube, there is always a resistance to flow. Decrease the diameter or increase the length, and the flow is reduced.

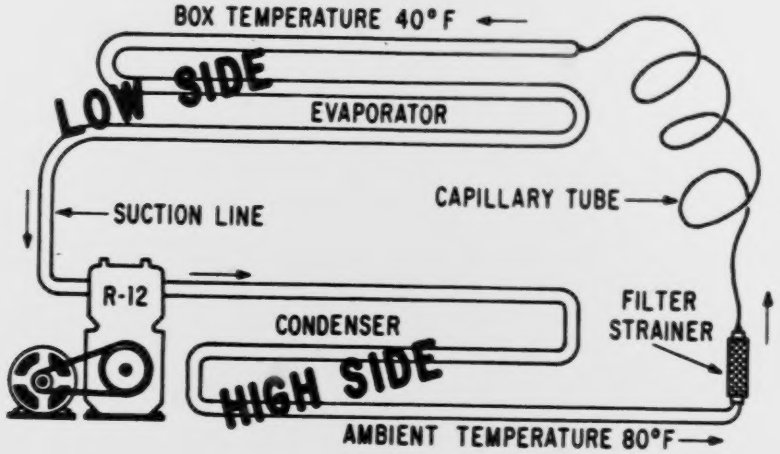

BOX TEMPERATURE 40° F
LOW SIDE
EVAPORATOR
SUCTION LINE
CAPILLARY TUBE
R-12
CONDENSER
FILTER STRAINER
HIGH SIDE
AMBIENT TEMPERATURE 80°F

Fig 4-22. Capillary tube in refrigeration system.

The capillary tube is designed to create enough resistance so that the pressure drop will allow the liquid refrigerant to begin to vaporize. This will occur near the inlet of the evaporator, where its temperature is cooled to the evaporator temperature and pressure. The capillary tube equalizes during the OFF cycle, minimizing the starting load on the compressor. Under the low load condition, fewer starting devices and less current will be required for the compressor motor. With the capillary tube the refrigerant charge is CRITICAL. Only a limited amount of refrigerant can be placed in the system. If too much refrigerant is in the system, the evaporator pressure will be above normal and the suction line will frost to the compressor. If there is not enough refrigerant, the evaporator will be starved. The tube is easily clogged or bent. A filter strainer should be installed at the inlet of the capillary tube to prevent dirt and foreign matter from clogging the tube.

A broken or plugged capillary tube requires to be replaced with exactly the same capillary tube as the original in its length and inside diameter. Approximately the same length of the replacement should be soldered to the suction line to make a heat exchanger. The variations in diameters of some capillary tubes are shown in figure 4-23.

CAPILLARY TUBES AND WIRE SIZES COMPARED

OD	ID	AWG	SIZE
.083	.031	No. 21	.028
.094	.036	No. 20	.032
.109	.042	No. 18	.0403
.114	.049	No. 17	.045
.120	.055	No. 16	.0508
.130	.065	No. 16	.064

Fig 4-23. Capillary tube diameter.

Many refrigerators have a capillary size of .114 inch outside diameter, (OD) and .049 inch inside diameter (ID) when used with R-12. Of course you can check the outside diameter with a micrometer, and the inside diameter with a wire. Notice that both the gage and diameter of wires are compared with capillary tube diameters in figure 4-23. Do not try to force a wire into a capillary tube to check the inside diameter. Also, make certain that the wire has not been burred on the end while being cut. You can check the diameter of a wire with a wire gage of a micrometer. In any case, the correct size wire should slip easily into the capillary tube.

When exact replacements are not available, you may install an adjustable capillary tube in the system. In this case, the capillary tube should be cut to equal the length of the one which it replaces. A heat exchanger of the same length is made by soldering the capillary to the suction line. Note that the ends of the capillary should be cut with a tube cutter to get a uniform end. Also, swage the appropriate ends of the tubing so that the capillary can be soldered into the system

Note: KEEP THE ENDS TAPED OR PLUGGED WITH RUBBER CAPS TO KEEP MOISTURE OUT WHILE THE SYSTEM IS OPEN. IF FITTINGS ARE AVAILABLE, THE TUBING MAY BE QUICKLY JOINED. HOWEVER, BECAUSE SUCH FITTINGS ARE EXPENSIVE, MOST SHOPS WILL USE A TORCH AND SOLDER THE CONNECTIONS.

After you have installed the capillary tube, evacuate it, dry it, charge it with refrigerant, and test it for leaks. For the replacement capillary tube with an external adjustment, set the capillary adjustment so that the evaporator frost evenly. Then make a final check for proper adjustment by seeing that the lines to and from the evaporator are not frosted.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the construction features of an automatic expansion valve.
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
   f. ______________________________
   g. ______________________________
2. How is the evaporator pressure varied?

   ____
3. Why is there a slight movement of the needle in the automatic expansion valve during normal operation?

   ____
4. How does the automatic valve function during the off cycle?

   ____

   ____

   ____
5. How does the expansion valve operate when the compressor starts?

   ____

   ____
6. How does the automatic expansion valve function during an increase in the high side pressure?

   ____

   ____

   ____
7. How does the expansion valve operate during the following?
   a. Increase in heat load: ______________________________

      ____
   b. Decrease in heat load: ______________________________

      ____

8. List the construction features of the thermostatic expansion valve.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

9. What is the principle of operation of the thermostatic expansion valve?

____

____

____

10. Identify the uses of the four different refrigerant charges used in the thermal bulbs.

a. Gas-charged: ______________________________

____

b. Liquid-charged: ______________________________

____

c. Cross-charged: ______________________________

____

d. Special-charged: ______________________________

____

11. What does a capillary tube do?

____

____

12. When should a capillary tube be replaced?

____

Work Unit 4-3. MOTOR AND SAFETY CONTROLS

CITE THE PURPOSE OF MOTOR CONTROLS.

STATE HOW THE THERMOSTATIC MOTOR CONTROL OPERATES.

CITE THE TYPES OF MOTIVATING UNITS AND THEIR OPERATING CHARACTERISTICS.

GIVE THE OPERATING CHARACTERISTICS OF A LOW PRESSURE MOTOR CONTROL, AND STATE HOW TO ADJUST IT.

DESCRIBE SOME OF THE COMMON TROUBLES OF A THERMOSTATIC MOTOR CONTROL.

You have learned that a refrigeration system depends on human aid to start and stop. This is not at all satisfactory, as it requires constant attention to maintain the temperature of the conditioned space within limits. By placing a switch that opens and closes in response to temperature changes in the power lead to the motor, a refrigeration system can be made completely automatic.

The purpose of a MOTOR CONTROL is to maintain a relatively constant temperature within the refrigerated space. This is done by starting the unit when the temperature rises and by stopping the unit when the temperature falls. Figure 4-24 illustrates the characteristics of an automatically controlled unit. From this diagram, you can see that the temperature within the refrigerated space is not constant. It is continuously rising and falling between two predetermined points (30° to 40° F).

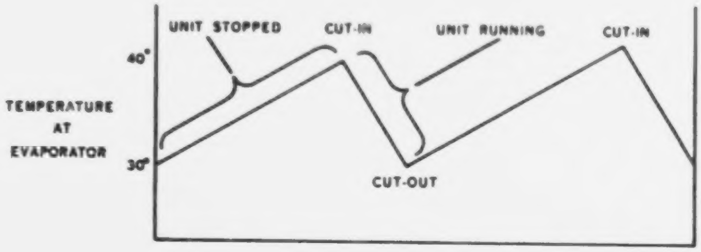


Fig 4-24. Characteristics of an automatically controlled unit.

A motor control is always connected electrically in series with the motor. Its location is illustrated schematically in figures 4-25 and 4-26. As you can see in these diagrams, the contact points of the control (represented by the "T" bar) allow current to flow to the motor when they bridge the gap in the power line, and they stop the current flow when they open.

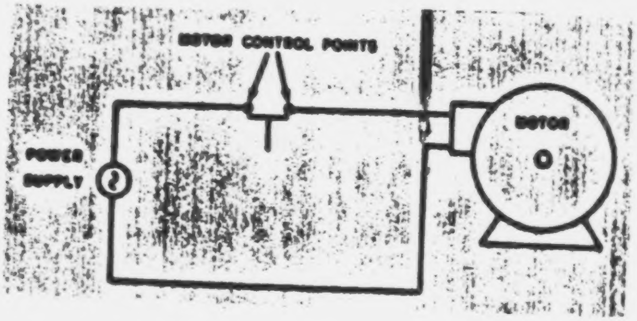


Fig 4-25. Motor control.

The THERMOSTATIC MOTOR CONTROL (TMC) senses temperature rather than pressure. These motor controls can be used on most types of refrigeration and air conditioning units. However, they must be used on all units that have automatic expansion valves or capillary tube refrigerant control devices.

The principle of operation of the TMC is a basic law of physics which states that matter will expand when heated and contract when cooled. If you apply heat to a sealed container that is completely filled with water, the pressure built up due to the heating could burst the container. If the temperature is reduced, the pressure exerted on the sides of the container also reduces. This physical law holds true if the container holds a liquid, a gas, or a combination of the two.

The TMC consists of two major parts: a housing, containing the operational lever mechanism, and a power element which is attached to the housing. The power element can be further broken down into three parts: a "feeler" bulb, a capillary tube, and a bellows. The three parts of the power element are connected together and are hollow. Inside this hollow element, there is a refrigerant charge of liquid, gas, or both. This charge is completely independent of the charge in the unit itself. The charge is very critical. Any leak, no matter how small, will render the power element inoperative.

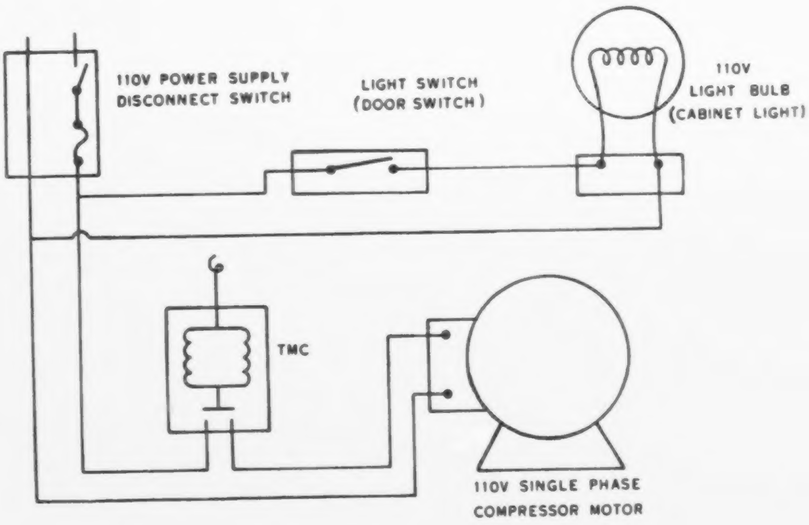


Fig 4-26. Location of motor control.

The bulb of the power element is located in such a position as to be sensitive to any change in the temperature of the control space. For domestic units, this location is on the evaporator so as to control the evaporator temperature. It might also be fastened inside the refrigerated space.

Any rise in temperature will heat the bulb, causing the charge to expand. This expansion will be transmitted through the capillary tube to the bellows, causing the bellows to expand. A short push rod is attached to the bellows and inserted into the housing to rest against one end of the lever system. The pressure of the power element will expand the bellows, pushing the rod against the lever. This lever will cause other levers to move, and the net result will be a set of electrical contact points closing. The closing of the points will cause the motor to start and the unit to be in operation.

As the temperature at the feeler bulb drops so will the temperature of the bulb drop. This causes a drop in power element pressure which reduces the push on the lever system. The lever system has a spring that opposes the power element pressure. As the element pressure drops, the spring pulls the points apart and stops the motor. Turning the adjusting knob clockwise compresses the spring, causing the cut-in temperature to rise. (More pressure in opposition to the power element demands more heat on the element to close the points.) Turning the knob counterclockwise will decrease spring tension and lower the cut-in point. The TMC has a second spring that works in conjunction with the power element instead of against it. This spring is used to set the "cut-out" temperature (on some controls) or the differential (on other type of controls).

There are four different types of motivating units or devices that are used to open and close the contact points in electrical controls: a BELLOWS, a DIAPHRAGM, a BOURDON TUBE, and a BIMETALLIC ELEMENT.

The BELLOWS (fig 4-27) may be connected directly to the condensing unit by tubing, or they may be actuated by the pressure in a temperature bulb. The pressure will cause the bellows to expand or contract. This movement opens or closes the electrical switch.

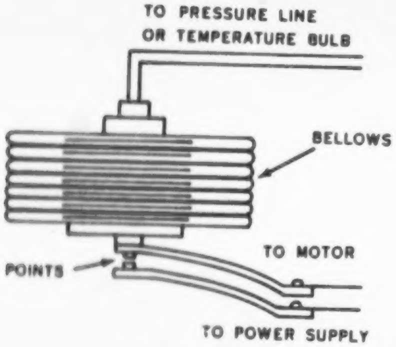

TO PRESSURE LINE
OR TEMPERATURE BULB
BELLOWS
TO MOTOR
POINTS
TO POWER SUPPLY

Fig 4-27. A bellows.

A DIAPHRAGM type power element (fig 4-28) is used in some controls. The complete power element consists of a thermal bulb, capillary tube, and diaphragm filled with a liquid or gas. Changes in temperature at the bulb will cause an increase in the volume of the liquid and a subsequent change in the diaphragm. This movement of the diaphragm opens or closes the electrical switch.

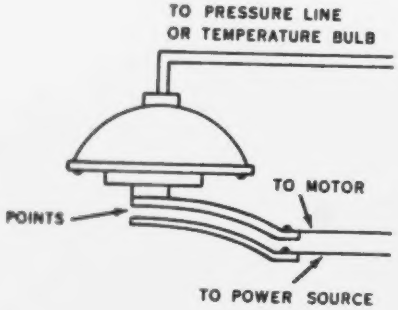

TO PRESSURE LINE
OR TEMPERATURE BULB
TO MOTOR
POINTS
TO POWER SOURCE

Fig 4-28. A diaphragm type power element.

A BOURDON TUBE (fig 4-29) is used in some pressure controls. The bourdon tube is the same as the one used in pressure and vacuum gages. An increase in pressure will tend to straighten the tube, while a decrease in pressure will cause it to curl up. The movement of the tube operates a switch.

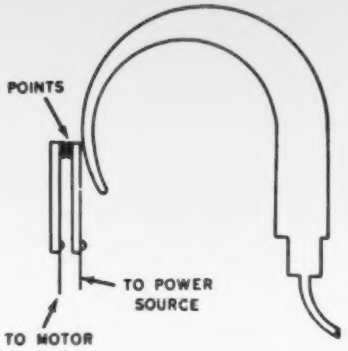
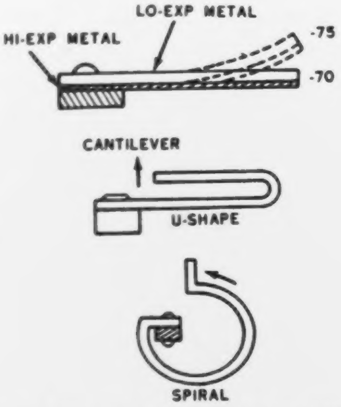


Fig 4-29. A bourdon tube.

A BIMETALLIC ELEMENT (fig 4-30) is used in air-conditioning thermostats. The element consists of two dissimilar metals fastened securely together. A change in temperature will cause the strip to bend. This motion opens or closes the electrical switch. Bimetal strips are classified as a temperature regulating or indicating device which works on the principle that two dissimilar metals with unequal expansion rates, welded together, will bend as temperature changes. Used as a thermostatic motor control, the entire control must be located inside the refrigerated space (room thermostat).



ARROW INDICATES DIRECTION OF MOTION UPON APPLICATION OF HEAT.

THE ABOVE FIGURE IS AN EXAGGERATED EXAMPLE OF MOVEMENT OF THE UNANCHORED END OF THE BIMETALLIC ROOM THERMOSTAT ON AN INCREASE IN AIR TEMPERATURE SHOWN BY ARROWS

Fig 4-30. A bimetallic element.

On studying the operation of a LOW-PRESSURE MOTOR CONTROL (LPMC), the first question that comes to mind is: How can a pressure activated device control temperature? Actually the answer is simple. Remember that the pressure above a liquid determines its boiling point. This characteristic is reliable and definite (refer to a temperature-pressure relationship chart). Refrigerant 12 under a pressure of 37 psi will boil at 40° F. Going one step further, if you have a system that uses R-12 and controls the evaporator pressure at 37 psi, you can expect a temperature of 40° F. Therefore, you have controlled the temperature by controlling the pressure. The motivating units for a pressure motor control are the same as the thermostatic motor control, with the exception of the bimetallic elements, which are strictly temperature sensitive.

There are many variations in the characteristics of individual types of motor controls. Generally, each control has adjustments of one kind or another. This permits the operator to select the operating condition best suited for a particular application. One of the most useful tools in adjusting controls is the pressure control setting chart.

If there is no control setting chart for a particular application, the next approach is to use the pressure-temperature relationship chart. In this case, estimate the desired temperature, convert these temperatures to pressures, and set the control for these pressures. As an example, the desired temperatures are 10° to 25° F, using R-22 as a refrigerant. The P-T chart shows that R-22 will produce these temperatures at a pressure of 33 to 49 psi. Set the control for these pressures and the unit should operate at the desired temperatures.

Note: TO USE THIS METHOD OF SETTING CONTROLS, THE OPERATOR MUST HAVE ENOUGH EXPERIENCE TO MAKE GOOD APPROXIMATIONS OF THE DESIRED OPERATING TEMPERATURES.

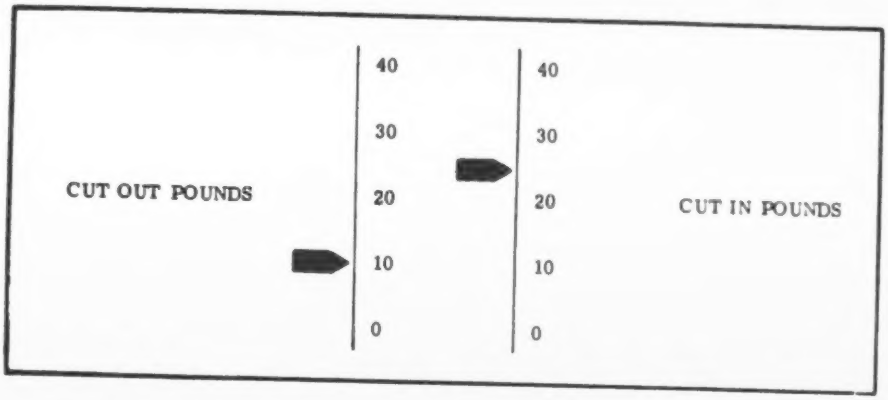


Fig 4-31. Cut-in and cut-out.

The next problem is to determine the adjustments that are to be made on a control in the field. There are two common adjustments of low-pressure controls: (1) adjustments of cut-in and cut-out (fig 4-31) and (2) the adjustment of cut-in and differential (fig 4-32). The difference in adjustment of these two types of controls is very minor, but it is crucial to the unit's operation. If you were to set the cut-out pressure when you should be setting the differential pressure, you would also change the temperature range of the unit. A pressure control on a walk-in refrigerator using R-12 refrigerant should cut-in at 25 psi and cut out at 10 psi. The differential is 15 psi. The adjusted control should appear as illustrated in either figure 4-31 or 4-32, depending on whether that particular control operates on cut-out pressure or on differential pressure. It is extremely important to realize that by setting the cut-in at 25 psi and the differential at 15 psi, the cut-out will automatically be 10 psi.

Note: ADJUSTING THE CUT-IN AND CUT-OUT (CUT-IN AND DIFFERENTIAL) TOO CLOSE TOGETHER WILL CAUSE THE UNIT TO CYCLE ON AND OFF TOO QUICKLY. THIS IS KNOWN AS SHORT-CYCLING.

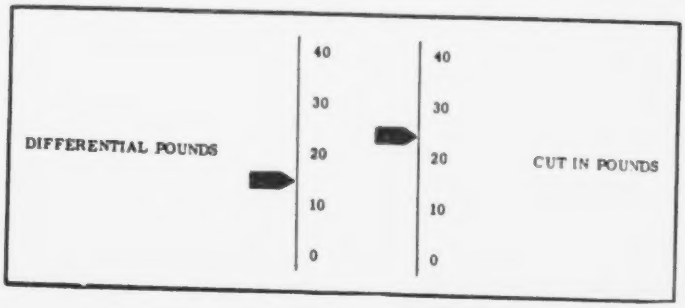


Fig 4-32. Cut-in and differential.

Thermostatic motor controls are very delicate instruments. However, if they are not misused, they will give years of trouble free service. Thermostatic motor controls are subject to several troubles, each of which usually requires replacement of the complete control. Some of the more common troubles are discussed.

Occasionally, the power element will lose part or all of its charge. This charge is very small, and any loss at all will cause the unit to fail. A kinked or clogged capillary tube will give the same indication as a loss of charge. Usually a power element failure requires the replacement of the complete control, but you can get replacement power elements for some controls. Needless to say, great care must be taken to ensure that you have the correct replacement item.

Even though there is snap action when the points open and close, they will burn. When this happens, the points will either stick closed or become pitted and never close. In some cases, the points can be filed and the control will operate satisfactorey for a period of time. This is only a temporary repair however, and the control should be replaced as soon as possible.

The parts of a TMC are light and do not move very far, but they do move many, times each day. One should not become to concerned about wear unless the unit has been in use for a long time.

Low and high voltages, high current flow, frayed insulation, bad electrical contacts, and various other electrical malfunctions will cause the TMC to fail. Electrical troubles can often be located and repaired without having to replace the control.

TINKERITIS, this malfunction is caused by unauthorized personnel attempting to adjust the controls. When this condition is found, readjust the control and instruct the user in the correct function and purpose of the control. Also, indicate that adjustment by unauthorized personnel usually results in inefficient operation.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Cite the purpose of motor controls.

2. State the principle of operation of a TMC.

3. One of the major parts of a TMC is the power element. Of what does it consist and how does it work?

4. What are the four types of motivating units that are used to operate contact points?

   a.
   b.
   c.
   d.

5. What is the principle of operation for an LPMC?

6. How is the cut-in and cut-out pressure adjusted on the LPMC?

7. Explain how you would adjust an LPMC's cut-in and differential pressure.

8. Describe the following troubles of a thermostatic motor control:

a. Loss of charge:

b. Burned contacts:

c. Wear:

d. Electrical:

e. Tinkeritis:

Work Unit 4-4. ELECTRICAL MOTORS

NAME THE TWO BASIC TYPES OF ALTERNATING CURRENT (AC) MOTORS.

NAME THE THREE TYPES OF OPEN MOTORS USED TO DRIVE COMPRESSORS.

NAME THE TWO TYPES OF MOTORS MOST COMMONLY FOUND IN HERMETIC COMPRESSORS.

The compression type of refrigeration system must have a power or energy source to turn the compressor. The electric motor is the most popular for small and medium size units. It is simple, quiet, and can be easily set up for automatic control.

Refrigerating systems operate either with an open or sealed-in (hermetic) motors. The open motor drives the compressor directly off the shaft or by means of a belt. The sealed-in or hermetic type motor is built inside the compressor dome. It usually drives the compressor directly.

Both alternating current (AC) and direct current (DC) may be used to operate electric motors. Alternating current motors are the most commonly used. Direct current motors are used in areas supplied with direct current only.

Motors are basically classified into two main divisions: SINGLE-PHASE and POLYPHASE.

In this work unit we will discuss some of the electrical motors that you may encounter in your job. We will discuss single-phase and polyphase induction motors, AC/DC universal motors, and synchronous motors.

First, lets' take a close look at the principles of operations for AC motors.

The speed of rotation of an AC motor depends upon the number of poles and the frequency of the electrical source of power:

$$\text{RPM} = \frac{120 \text{ X frequency}}{\text{number of poles}}$$

Since an electrical system operates at 60 cycles (hertz), an electric motor at this frequency operates at about 2-1/2 times the speed of the old 25 cycle motor with the same number of poles. Because of this high speed of rotation, 60 cycle AC motors are suitable for operating larger refrigeration systems.

Alternating current motors are rated in horsepower output, operating voltage, full load current, speed, number of phases, frequency, and whether they operate continuously or intermittently.

All single-phase induction motors have a starting winding (see fig 4-33) since they cannot be started with only the single-phase winding on the stator. After the motor has started, this winding may be left in the circuit or be disconnected by a centrifugal switch.

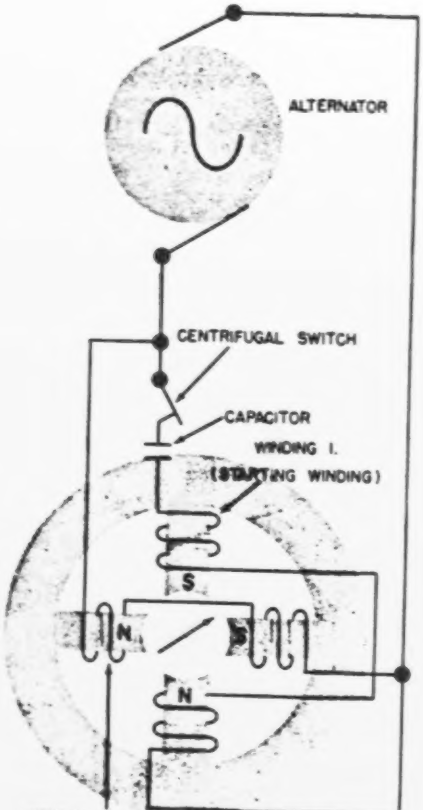


Fig 4-33. Single-phase motor with capacitor starting winding.

Both single-phase and three-phase motors operate on the principle of a rotating magnetic field. As a simple example of the principle of the rotating field, imagine a horseshoe magnet held over a compass needle. The needle will take a position parallel to the magnetic flux passing between the two poles of the magnet. If the magnet is rotated, the compass needle will follow.

A rotating magnetic field can be produced by a two-phase or three-phase current flowing through two or more groups of coils wound on inwardly projecting poles of an iron yoke. The coils on each group of poles are wound alternately in opposite directions to produce opposite polarity, and each group is connected to a separate phase of voltage.

You can understand this action with the aid of figure 4-34, which shows a four pole stator field energized by two windings connected to two separate phase voltages. Winding No. 1 of the motor is 90° out of phase with winding No.2, which causes the current in winding No.1 to lead the current in winding No. 2 by 90°, or by 1/240 second, assuming the frequency of the AC power supply is 60 cycles per second. Winding No.1 can be referred to as phase 1, and the winding No.2 as phase 2.

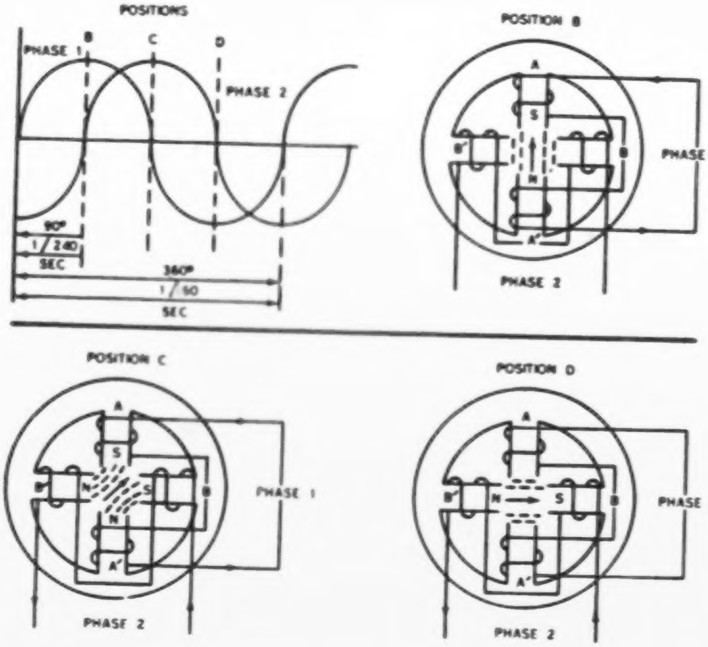


Fig 4-34. Production of a rotating magnetic field.

The direction of the magnetic field is indicated by a magnetic needle (considered as a north pole for clarity). The needle will always move to a position where it will line up with the magnetic flux passing from pole to pole. Notice the phase relationship of the two voltages which are applied to the two phase windings of the field. Phase 1 supplies current to the coils on pole A and A', and phase 2 supplies current to the coils on poles B and B'. The two currents are 90° out of phase, with phase 1 leading.

At position B, the current in phase 1 is at a maximum and the poles of A and A' are fully magnetized. The poles of coils B and B' are not magnetized, since the current in phase 2 is zero. Therefore, the magnetic needle points in the direction shown. At position C, the current in coils A and A', phase 1, has decreased to the same value to which the current in coils B and B' phase 2, has increased. Since the four poles are now equally magnetized, the strength of the field is concentrated midway between the poles, and the magnetic needle takes the position shown.

At position D, the current of phase 1 is zero through coils A and A', and there is no magnetism in these coils. There is maximum current through coils B and B'; the magnetic needle takes the crosswise position. This action is repeated during successive cycles of the flow of the alternating currents, and the magnetic needle continues to revolve in the same direction within the field frame as long as the two phase currents are supplied to the two sides of the coils.

In an induction motor with two poles for each phase winding, the north pole would glide from one pole to the other in 1/120 second and make a complete revolution of 1/60 second, which would be at the rate of 3600 rpm. If the compass needle is replaced by an iron rotor wound with copper bar conductors (usually called a squirrel cage rotor because the conductors resemble a squirrel cage, as shown in figure 4-35, a secondary voltage is induced in the conductors by mutual induction much in the manner that the secondary voltage is developed in a transformer.

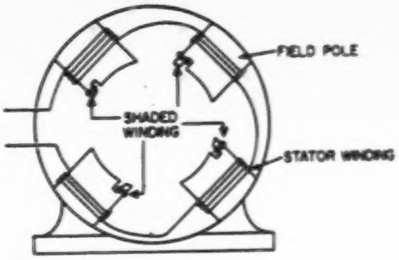


Fig 4-35. Shaded pole motor stator windings.

Current flowing in the conductors produces a magnetic field which reacts on the rotating magnetic field and causes a rotation of the iron core similar to the rotation of the magnetic needle. The direction of rotation may be reversed by reversing the connections of one phase.

The stator windings of a SHADED-POLE MOTOR differ from other single-phase motors by definitely projecting field poles (see fig 4-36). A low resistance, short circuited winding or copper band is placed across one tip of each pole, from which the name "shaded-pole" is derived. As the current increases in the stator winding, the flux increases. A portion of this flux cuts and induces a current in the shaded winding. This current sets up a flux which opposes the flux inducing the current; therefore, most of the flux passes through the unshaded portion of the pole, as shown in figure 4-36. When the current in the winding and main field flux reaches a maximum, the rate of change is zero, so no electromotive force is induced in the shaded winding. A little later the shaded winding current, which lags the induced electromotive force, reaches zero, and there is no opposing flux. Therefore, the main field flux passes through the shaded portion of the field pole. This results in a weak rotating magnetic field with sufficient torque to start small motors. Because of the low starting torque, shaded-pole motors are furnished in ratings up to approximately 1/25 horsepower and are used with small fans, timing relays, small motion picture projectors, and various control devices. Shaded-pole motors are designed for a specific direction of rotation that cannot be changed after the motor is assembled.

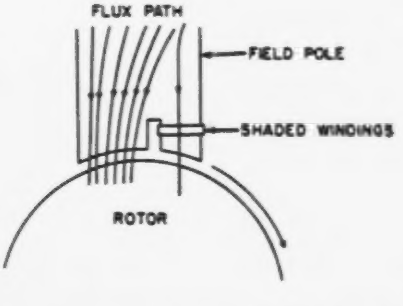


Fig 4-36. Flux path in a shaded-pole motor.

SPLIT-PHASE MOTORS contain two windings, the main winding and the starting winding. The main winding is wound on the stator and the starting winding is wound on top of the main winding in such a manner that the centers of the poles of the two windings are displaced by 90^{o}. The windings are connected in parallel (see fig 4-37) to the same supply voltage, therefore, the same voltage is applied to both windings. The starting winding is usually wound with fewer turns of small size wire and has iron on only two sides. It, therefore, has less inductance than the main winding, which has a low resistance and is surrounded by iron on all sides except one. When the same voltage is applied to both windings, the current in the main winding lags the voltage more than the current in the starting winding. This produces a rotating field which starts the motor. As the motor approaches full speed, a centrifugal mechanism mounted on the rotor opens a centrifugal switch (see fig 4-37) and disconnects the starting winding from the line. If the centrifugal mechanism should fail to open the switch, the motor will run hot because of the high resistance of the starting winding and will burn out the starting winding if allowed to run any length of time. This is the most frequent cause for failure of split-phase motors. The split-phase motors are usually furnished in ratings from 1/60 to 1/3 horsepower and are desirable for use in machine tools, office equipment, pumps, fans, blowers, oil burners, kitchen appliances, and laundry equipment. Split-phase motors may or may not have a built-in thermal overload relay for the protection of the motor during an overload. The relay is usually of the automatic type, opening when the current in the windings is above normal and automatically resetting when the current is restored to normal. To reverse the split-phase motor, reverse the leads of either the starting winding or the running winding.

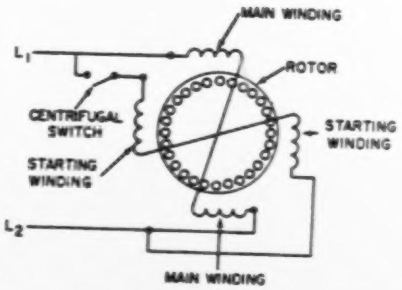


Fig 4-37. Schematic of a single-phase, split-phase motor.

The CAPACITOR-START MOTOR is so called because a capacitor instead of resistance is used to split the phases. The capacitor, usually mounted on top of the motor, is usually connected in series with the starting winding to provide the necessary shift in time phase of the current flowing through it. This capacitor is usually intermittently rated and must be disconnected for normal operation. This disconnection is usually done by a centrifugal mechanism mounted on the rotor. When the motor is stopped, the switch closes and is in the correct position when the motor is started again. The capacitor type motor has a higher starting torque at less current than the split-phase motor and also provides a greater capacity. Capacitor-start motors are usually furnished in ratings from 1/6 to 1 horsepower and are used on compressors, pumps, fans, and machine tools.

The PERMANENT-SPLIT CAPACITOR MOTOR is similar to the capacitor-start motor, except that the permanent capacitor (see fig 4-38) is connected in series with the starting

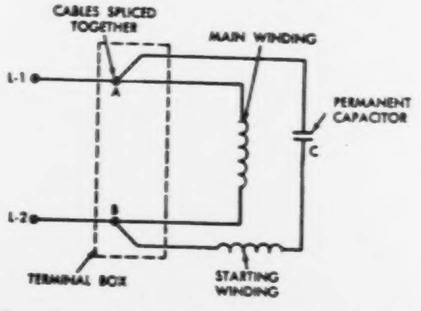


Fig 4-38. Schematic of a single-phase permanent-split capacitor motor.

winding permanently and is not removed from the circuit during operation by a centrifugal switch. This eliminates the need for a centrifugal switch and switch mechanism. The capacitor is continuously rated and is selected to give best operation at full speed while sacrificing starting torque. Permanently split capacitor motors develop 40 to 60 percent starting torque and are used on easily started loads such as fans and blowers.

The CAPACITOR-RUN MOTOR has two capacitors connected in parallel portions (see fig 4-39). One, a RUNNING CAPACITOR, is a continuously rated capacitor and remains in the circuit while the motor is running. The other, a STARTING CAPACITOR, is intermittently rated and is used in the circuit during starting only. The starting capacitor is removed by a centrifugal mechanism and switch as the motor approaches full speed. Therefore, the capacitor-run motor is a combination of the capacitor-start and the permanent-split capacitor motors. This motor has a high starting torque as well as good running characteristics and is generally furnished in ratings of 1/2 horsepower and larger. Capacitor motors may be reversed by changing the leads to the starting winding at the motor terminals.

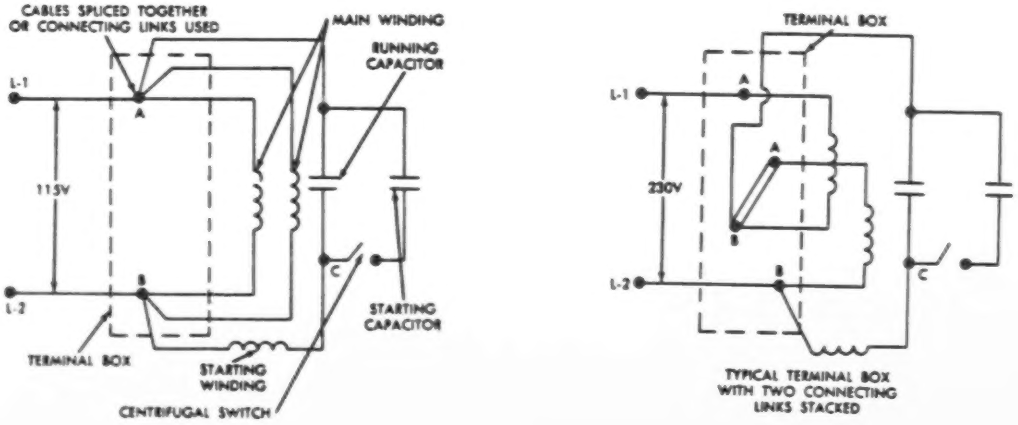


Fig 4-39. Schematic of a single-phase dual voltage capacitor run motor.

The THREE-PHASE AC INDUCTION MOTOR is also called a squirrel cage motor. The rotating magnetic field of the three-phase motor operates in the same manner as a two-phase motor. The difference between a two-phase and a three-phase motor is in the windings. The two-phase windings are placed 90° apart where, the three-phase windings instead are placed 120° apart. This means that the currents that produce the magnetic field reach a maximum 1/180 second apart in a 60 cycle circuit. Notice figure 4-40 which shows the connection of a wye connected stator in a three-phase induction motor. The rotor of the motor is represented by the compass needle, which points in the direction of the magnetic field and revolves as the magnetic field revolves. The individual current waves are shown along the phase wires as they actually are during operation. Notice the current in phase A reaches a maximum at position 1 and at that instant the currents in phases B and C are both negative.

At position 2, 1/180 second later, the current is at a maximum in phase B and is negative in phases A and C. At position 3, which is 1/180 second later than position 2, the current is at maximum positive in phase C and is negative in phases A and B. In the diagrams, the magnetic field caused by the maximum positive current is shown in heavy dark lines. The other poles are indicated with dotted lines. The rotor, like the single-phase motor, follows the rotating magnetic field of the stator winding.

The speed of the induction motor is always less than the speed of the rotating field of the stator. If the rotor were to turn at the same speed as the rotating field, the rotor conductors would not be cut by any magnetic field and no voltage would be induced in them. No current would flow, thus, there would be no magnetic field in the rotor and, hence, no torque.

A three-phase induction motor exerts a torque when at rest and, therefore, starts itself when the proper voltage is applied to the stator field coils. To reverse the direction of rotation of a three-phase motor, reverse the leads of any two phases.

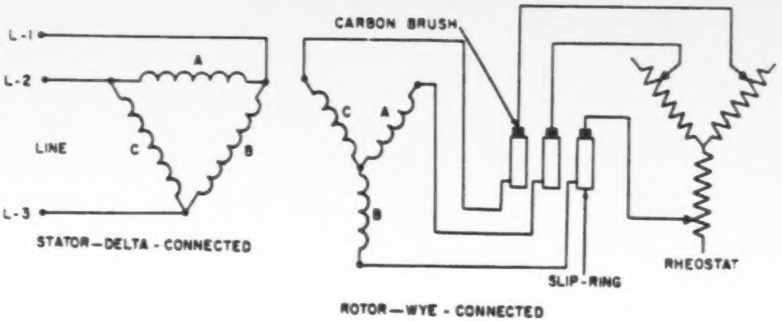


Fig 4-40. Schematic of a three-phase slipring induction motor.

The three-phase slipring (wound rotor) induction motor is wound with a three-phase drum winding. The winding are connected WYE (Y) or DELTA (a wye connection is shown in figure 4-40), and the three leads are brought out and connected to three electrical contact rings (sliprings) which are secured to the shaft. Brushes riding on the rings are connected to an external resistance through which the rotor circuit is completed. Motors containing wound rotors have a high starting torque with low starting current plus adjustable speed.

SYNCHRONOUS MOTORS are divided into two classes according to their size and application. The larger horsepower motors use three-phase power and have separately excited salient pole rotors. The smaller motors are usually furnished as fractional horsepower motors and obtain their rotor excitation current through induction. Although an induction motor is considered as a constant speed motor, it is subject to approximately 10 percent variation in speed under various load conditions, since the operating torque depends upon the percentage of slip between the rotating magnetic poles and the magnetic flux of the rotor. The speed of a synchronous motor is controlled by the frequency of the alternating current power source and is, therefore, maintained with a high degree of accuracy. The smaller size synchronous motors are constructed as reluctance motors or hysteresis motors, which are described in following paragraphs.

The stator of a RELUCTANCE MOTOR is similar in construction to that of the single-phase induction motor and may be of the shaded-pole, split-phase, or capacitor type. The squirrel-cage rotors have grooves cut to allow the addition of salient poles. The number of salient poles mounted on the rotor corresponds to the number of rotating stator poles. The motor starts as an induction motor, but, upon reaching a speed near synchronism, it pulls into step because of the salient poles and operates at exactly synchronous speed. The reluctance motor, unlike the larger size synchronous motor (which has on the rotor a field winding supplied with direct current excitation and which operates at unity or at a leading power factor with high efficiency), operates at a lagging power factor and has a rather low efficiency. Therefore, the reluctance motor is used only where exact synchronous speed is required, such as in electric clocks, time switches, relays, and meters.

The construction of the HYSTERESIS MOTOR is similar to that of the reluctance motor except for the rotor. The rotor does not have a squirrel cage winding. Instead the rotor core is usually made of a ring of metal having permeability, such as chrome or cobalt steel. The highly magnetic core material retains its magnetism over a period of time and this enables the rotor to reach its synchronous speed. Hysteresis motors develop a constant torque from zero synchronous speed and are used in the timing devices of clocks, they will operate unattended for long periods of time.

UNIVERSAL MOTORS are designed for operation from either DIRECT CURRENT or SINGLE-PHASE ALTERNATING CURRENT and are all of the series-wound type. That is, the field windings are connected in series with the armature windings. Universal motors are divided into two types: the straight series-wound universal motor and the compensated series-wound universal motor.

The STRAIGHT SERIES-WOUND UNIVERSAL MOTOR has the field windings connected in series for opposite polarity, in the same manner as the field winding of any direct current motor, and then in series with the armature (see fig 4-41). This type motor uses salient type pole pieces (see fig 4-42) for mounting the field windings and is usually furnished in larger sizes for special applications. The motor full speed is rated from 1800 rpm on the larger sizes to 5000 rpm on the smaller sizes and no load speeds ranging from 12,000 to 18,000 rpm. Since these motors run at dangerously high speed at no load, they are usually built into the equipment being driven. This type is used in portable machines and portable equipment in general.

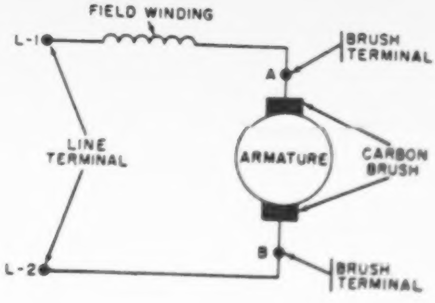


Fig 4-41. Straight series-wound universal motor.

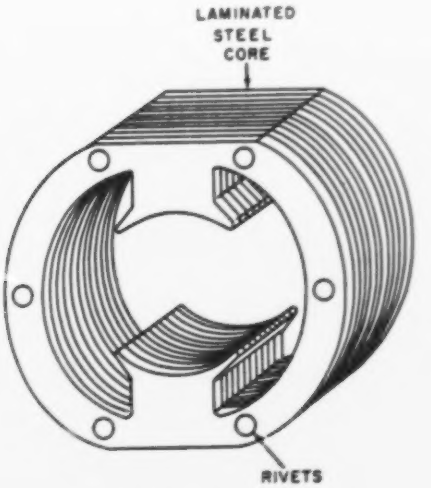


Fig 4-42. Salient pole laminated steel core of a universal motor.

The COMPENSATED SERIES-WOUND UNIVERSAL MOTOR contains a main winding and a compensating winding connected in series with the armature (see fig 4-43). The core of this type of motor is similar to the construction of the core of the split-phase alternating current motor (see fig 4-44). The main winding is usually placed in the slots first and the compensating winding is placed over it, 90 electrical degrees away. The compensating winding reduces the reactive voltage present in the armature when alternating current is used. It has a better commutation and power factor than does the straight series-wound universal motor, and usually comes in higher horsepower ratings. Compensating series-wound universal motors are used with portable tools, office machines, vacuum cleaning equipment, and portable equipment in general.

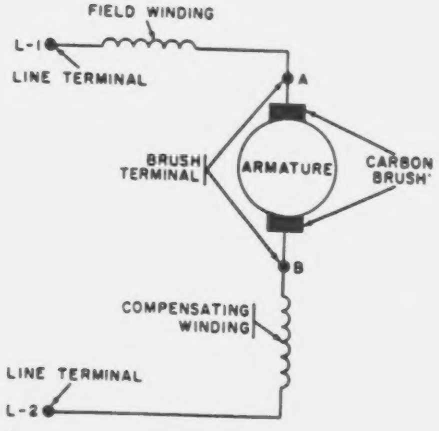

FIELD WINDING
L-1
LINE TERMINAL
A
BRUSH TERMINAL
ARMATURE
CARBON BRUSH
B
COMPENSATING WINDING
LINE TERMINAL
L-2

Fig 4-43. Compensated series-wound universal motor.

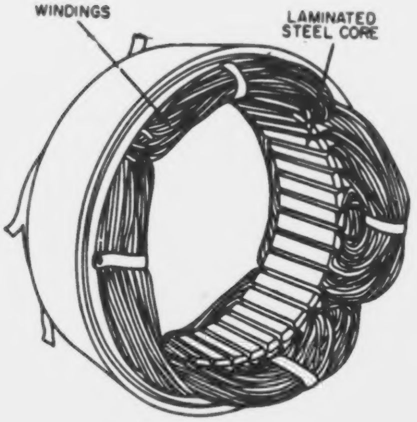

WINDINGS
LAMINATED STEEL CORE

Fig 4-44. Salient pole liminated steel core of a universal motor.

REPULSION-START INDUCTION, CAPACITOR-START INDUCTION, and INDUCTION POLYPHASE are the three main motors which you can expect to find that drive the open type compressors. CAPACITOR-START INDUCTION and INDUCTION TWO-PHASE and POLYPHASE are two types used in the hermetic type compressors. The fan motors used in the condenser and evaporator are normally of the SHADED-POLE and CAPACITOR TYPE.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are the two basic types of AC motors?

   a. ______________________________

   b. ______________________________

2. What are the three types of motors that you can expect to find driving open type compressors?

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. What are the two types of motors used in the hermetic type compressors?

   a. ______________________________

   b. ______________________________

4. What are the two types of motors that are used as condenser and evaporator fan motors?

   a. ______________________________

   b. ______________________________

SUMMARY REVIEW

In this study unit, you have learned the most common cycle contols and devices that start, stop, regulate and/or protect the refrigeration cycle and its components. You also, learned how the controls respond to temperature, pressure and humidity to control the operation of the system. In addition, you learned the different types of motors that are employed in refrigeration systems and the protective and control devices used to control the motors.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. It is used to visually determine if a refrigeration system has a sufficient charge.
2. As close as possible to the receiver, but far enough downstream to avoid any disturbance from valve action.
3. a. Give the system more refrigerant.

   b. Reduce the pressure drop.

   c. Further subcool the liquid refrigerant.
4. They relieve dangerous, excessive pressure from the system.
5. a. The fusible plug will melt at a predetermined temperature.

   b. The ruptured disk is designed to burst when pressure reaches a dangerous level.

   c. The spring loaded relief valve will open at a preset pressure and close automatically at 10 to 20 percent below its opening pressure.

6. They turn the water on or off and regulate its flow.

7. Between the water supply and the condenser

8. a. Electric water valve
    b. Pressure operated valve
    c. Thermostatic water valve

9. a. Suction pressure control valve
    b. Two temperature valve
    c. Suction pressure control valve
    d. Two temperature valve
    e. Two temperature valve
    f. Two temperature valve

10. They prevent the reversal of flow.

11. The swing checks use a hinged disk which seats against a tilted bridge and the lift check disk seats on a horizontal bridge wall.

12. A defrost timer is a device that starts the defrost cycle automatically.

13.. The mechanism within the clock activates a cam that operates various switches. Clocks can be set to defrost the system at scheduled intervals such as at each cycle, or every few hours, or once a day, or after a few hours of running time of the compressor.

14. Solenoid valves are used to close or open a circuit. When a solenoid is energized, a magnetic armature or plunger, moves upward toward the center of the coil, thus opening the valve.

15. a. Direct acting
    b. Pilot operating

Work Unit 4-2.

1. a. Closing spring
    b. A needle and needle seat
    c. Drive pins
    d. A diaphragm
    e. Opening spring
    f. Adjusting screw
    g. A vent hole

2. By changing the pressure of the opening spring

3. This movement regulates the refrigerant flow.

4. The valve remains open until the evaporator pressure overcomes the opening spring pressure and the valve closes.

5. The valve does not open immediately, it will not open until the compressor reduces the evaporator pressure. As this happens, it becomes less than the opening spring pressure and the valve opens.

6. It forces more refrigerant through the valve, causing an increase in evaporator pressure, which unbalances the valve, causing it to close silghtly and reduce the refrigerant flow.

7. a. An increase in heat load causes the refrigerant to vaporize faster.

   b. A decrease in heat load causes the evaporator pressure to decrease, thus to open the valve.

8. a. A thermal bulb

   b. Capillary

   c. Diaphragm

   d. Push rods

   e. Valve seat and needle

   f. Spring

   g. Adjusting screw

9. It regulates the flow of refrigerant entering the evaporator, maintaining a fully active evaporator regardless of the heat load and pressure changes.

10. a. Uses the same refrigerant as the system and can be used in applications where temperatures are as low as 26°.

    b. Uses a different fluid than that used in the system and can be used where temperatures reach 35° to 37° F.

    c. Uses a special type charge and is used where temperatures reach -40° F.

    d. Uses the same fluid as is used in the system. Operates on the principle of expansion and contraction with a temperature change.

11. The capillary tube creates resistance in flow so that the pressure drop will allow the liquid refrigerant to vaporize.

12. With a length of small diameter, seamless copper tubing when broken or plugged.

Work Unit 4-3.

1. They maintain a relatively constant temperature within the refrigerated space.

2. All matter will expand when heated and contract when cooled.

3. It consists of a feeler bulb, capillary tube, and bellows. The power element is charged with a refrigerant and is placed in a position to be sensitive to a temperature change. This change will cause the elements' charge to expand or contract, causing the bellows to expand or contract accordingly. This activation of the bellows moves a system of levers that ultimately opens or closes a set of electrical contacts.

4. a. Bellows

   b. Diaphragm

   c. Bourdon tube

   d. Bimetallic element

5. The variance in pressure causes a difference in boiling temperature of a liquid.

6. Use the control setting chart or the pressure-temperature relationship chart to find the desired temperatures for cut-in or cut-out. Then move the point setter on the control.

7. Use the control setting chart or the pressure-temeprature relationship chart to find the desired temperature for cut-in and differential. Then set the differential set indicator to the desired temperature.

8. a. The power element will lose some or all of its charge which will render it inoperable.

   b. Points will burn and become pitted which will cause then to stick close or remain open.

   c. Very old unit may wear out for they move many times during the day.

   d. High or low voltages, high current flow, frayed insulation, bad contacts are all causes of electrical troubles.

   e. This is the inexperience or unauthorized personnel attempting to repair or adjust the controls.

Work Unit 4-4.

1. a. Single-phase

   b. Polyphase

2. a. Repulsion-start induction

   b. Capacitor-start induction

   c. Induction polyphase

3. a. Capacitor-start induction

   b. Induction polyphase

4. a. Shaded-pole

   b. Capacitor

STUDY UNIT 5

AIR-CONDITIONING

STUDY UNIT OBJECTIVE: WITH THE AID OF REFERENCES, YOU WILL IDENTIFY THE PSYCHROMETRIC CHART AND HOW TO OBTAIN INFORMATION FROM THE CHART. WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY INSTALLATION AND MAINTENANCE OF VARIOUS AIR CONDITIONING EQUIPMENT AND AIR-FLOW INSTRUMENTS.

Today air-conditioning is used by the military to control the environment in which troops and equipment operate. This environmental control extends not only to the temperature of the space, but to controlling the humidity (moisture content), removal of foreign and undesirable particles from the air, and distribution of the conditioned air throughout the desired space. Moisture, heat, and foreign matter enter the air in many ways. The human body gives off heat and moisture. The average adult engaged in light work will give off approximately 500 Btu's of heat per hour and will consume and give off about three lbs of water daily. Equipment will give up heat to the surrounding atmosphere either through friction caused by mechanical motion or by heat created electricity flowing through wires, contacts, motors, etc. Moisture and foreign particles can enter a conditioned space through windows, doors, minute cracks, ventilation systems, and by people carrying them on their person and clothes. In order to maintain an environment at a specific level of control, air-conditioning equipment is used to raise or lower temperatures, remove moisture and foreign particles, and to distribute air evenly throughout the space to be controlled.

Work Unit 5-1. AIR-CONDITIONING AND THE PSYCHROMETRIC CHART

CITE THE WAYS THE PROPERTIES OF AIR AFFECT AIR-CONDITIONING.

DEFINE VARIOUS TERMS RELATED TO AIR-CONDITIONING.

GIVE THE PURPOSE OF THE PSYCHROMETRIC CHART AND STATE SELECTED CHARACTERISTICS OF THE PSYCHROMETRIC CHART SCALES.

USING A TYPICAL PSYCHROMETRIC CHART AND GIVEN WET AND DRY BULB TEMPERATURE, DETERMINE SELECTED PROPERTIES OF AIR.

If you look at air-conditioning carefully, you will see that air itself is used to condition the occupied space. Consequently, to properly condition the space, the refrigeration technician must be able to analyze the air in the room and then supply the right amount of conditioned air.

AIR-CONDITIONING is a process of taking air and controlling its temperature, humidity, cleanliness, and distribution balance so that it will meet the requirements of the space to be conditioned.

A complete air-conditioning system will provide a complete control of these conditions all year around. This includes:

- Maintaining a desired winter temperature in a conditioned space. This requires an automatic control of the heating device.
- Maintaining a desired humidity in winter, which is usually a period of low humidity. This requires some type of automatic control to add moisture to the air (humidifier).
- Providing a desired de-humidification during summer months. This is obtained through automatic control of the air across the evaporator coils.

Basically, air is a mixture of two basic gases, nitrogen and oxygen. Nitrogen accounts for approximately three-fourths of the air's weight by volume, while oxygen accounts for the remaining one-fourth. There are, of course, traces of a few other gases in the atmosphere, all the time. However, they do not usually appear in volumes significant enough for any of them or all of them together to be important factors. One remaining element is found in air and that is water vapor. The amount of water vapor in the air has a great influence on equipment cooling and on human comfort. Such atmospheric moisture us called "HUMIDITY".

The water vapor in the air is neither absorbed nor dissolved by the air. The mixture is a simple physical one, just as sand and water are when mixed. The temperature of the water vapor is always the same as that of the surrounding air.

When the air contains all of the water it can hold, it is termed "saturated air." The amount of moisture present at the saturation point varies with the temperature of the air. Thus, the higher the temperature of the air, the more moisture the air can hold.

Let's take a look at some of the various terms related to air-conditioning.

- SPECIFIC HEAT - The so called sensible heat required to cause a temperature change in substances varies with the kind and amount of the substance. This property is called the specific heat of a substance, i.e. the amount of heat required to raise 1 pound of the substance 1° F. This value is good for computations, provided no change of state is involved. If, however, a change of state should occur, the specific heat of the substance also changes. To determine the amount of heat necessary to cause a temperature change in a substance, multiply the weight of the substance by its specific heat. Then multiply that answer by the temperature change (Btu = specific heat X weight X temperature change).

- LATENT HEAT - "Latent heat" is the heat that is added or taken from a substance, causing a change of state. These changes of state occur without any changes in temperature or pressure. Latent heat is commonly referred to as "hidden heat," "latent heat of fusion," "latent heat of vaporization," and "latent heat of condensation."

- TOTAL HEAT - Any mixture of dry air and water vapor (atmospheric air) does contain both sensible and latent heat. The sum of these two heats is termed "total heat," and it is usually measured from 0° F.

As you remember, these types of heat were covered in previous study units. You will now be given some terms which were mentioned earlier but were not covered as throughly as they will be now.

In air-conditioning, the air temperature is listed more accurately as the "DRY-BULB TEMPERATURE." This temperature is taken with the sensitive element of the thermometer in a dry condition. Unless otherwise specified, all air temperatures are dry-bulb temperature.

- WET-BULB TEMPERATURE - This is the temperature at which air ceases to be cooled by the process of evaporation. A wet-bulb thermometer, which is a part of a sling psychrometer, is an ordinary thermometer with a cloth sleeve placed around its bulb and made wet with water (distilled water is preferred). The cloth sleeve should be clean and free from oil and thoroughly wet with clean, fresh water. The water in the cloth sleeve is evaporated by the current of air at high velocity. The evaporation withdraws heat from the thermometer bulb, thus lowering the temperature. This temperature is measured in degrees Fahrenheit. The difference between the dry-bulb and wet-bulb temperature is called the "WET-BULB DEPRESSION." If the air is saturated, evaporation cannot take place, and the wet-bulb temperature is the same as the dry-bulb. Complete saturation, however, is not usual, and a wet-bulb depression is normally to be expected.

The wet-bulb thermometer indicates the total heat of the air being measured. If air at several different times or in different places is measured, and the wet-bulb temperature remain the same for all, the total heat would be the same in all, though their sensible heats and respective latent heats might vary considerably.

- DEW-POINT TEMPERATURE - The dew point depends upon the amount of water vapor in the air. If air at a certain temperature is not saturated, i.e. if it does not contain the full quantity of water vapor that it can hold at that temperature; and the temperature of that air then falls, a point is finally reached at which the air is saturated for the new lower temperature and condensation of the moisture then begins. This point is the DEW-POINT TEMPERATURE of the air for the quantity of water vapor present at that time.

The definite relationships between the three temperatures just mentioned should be clearly understood. These relationships are:

- When the air contains some moisture but is not saturated, the dew-point temperature is lower than the dry-bulb temperature; whereas the wet-bulb temperature lies between them.
- As the amount of moisture in the air increase, the difference between the temperatures grows less.
- When the air is saturated, all three temperatures are the same.

- RELATIVE HUMIDITY - This is the ratio of the amount of moisture in the air compared to what it could hold at the same temperature. It is a percentage expression of the grains of moisture contained in the air.

- GRAINS OF MOISTURE AND SPECIFIC HUMIDITY - When you encounter both "GRAINS OF MOISTURE" and "SPECIFIC HUMIDITY", keep in mind that these terms mean the same thing. By grains of moisture or specific humidity, we mean the unit of measurement expressing the actual amount of moisture contained in one pound of dry air. Relative humidity can be determined from this measurement, but you use percent of relative humidity to determine grains of moisture. A grain of moisture is about the same as a drop of water. A pound of water (about 1 pint) contains 7,000 grains.

- POUNDS OF MOISTURE - By "pounds of moisture" per pound of dry air, we mean the weight of the grains of moisture contained in 1 pound of dry air.

Air is the primary medium that is used to control the conditions in the controlled space. Air can be used to control the humidity and temperature for three general purpose uses: personnel or comfort cooling, equipment cooling, and process cooling. New applications for air-conditioning are, of course, being found continually.

The purpose of air conditioning is to control temperature, humidity, and the circulation of the air.

The field of psychrometric study is a breakdown of the various properties contained in the air and a graphic analysis of the air's conditions. If the technicians understand all that they can about the air being used, then their understanding of the equipment's operation becomes more realistic.

- PSYCHROMETRIC CHART - The psychrometric chart is the tool used to analyze the relationship of the properties of the air. (See the fold-out at the end of this study unit.) The technician should master at least the meaning of the chart in order to properly understand the air that is being conditioned.

The relationships of the properties of the air are graphically illustrated on the psychrometric chart as a series of lines and curves that have been scientifically formulated to show the whole picture of the air being studied.

The comparison of the lines and curves at intersecting points of the scales on the chart gives us a very comprehensive analysis of the air being studied. More than one condition may appear on the chart to give us more accurate analysis and true operation of the system in consideration.

Once the dry-bulb temperature and wet-bulb temperature have been obtained, you can then begin the plotting procedures by using the psychrometric chart scales. In order to know what you are doing, the scales that are read on the psychrometric chart are the first point of identification on the chart. The psychrometric chart contains lines and curves which have corresponding scales and which are read at intersecting points.

In figure 5-1, the lines and scales are identified; whereas, the later figures that accompany the terms will point out the names of the lines corresponding to each set of scales. Basically, there are five sets of scales that are used on the psychrometric chart. Some of the readings will be scale differential readings.

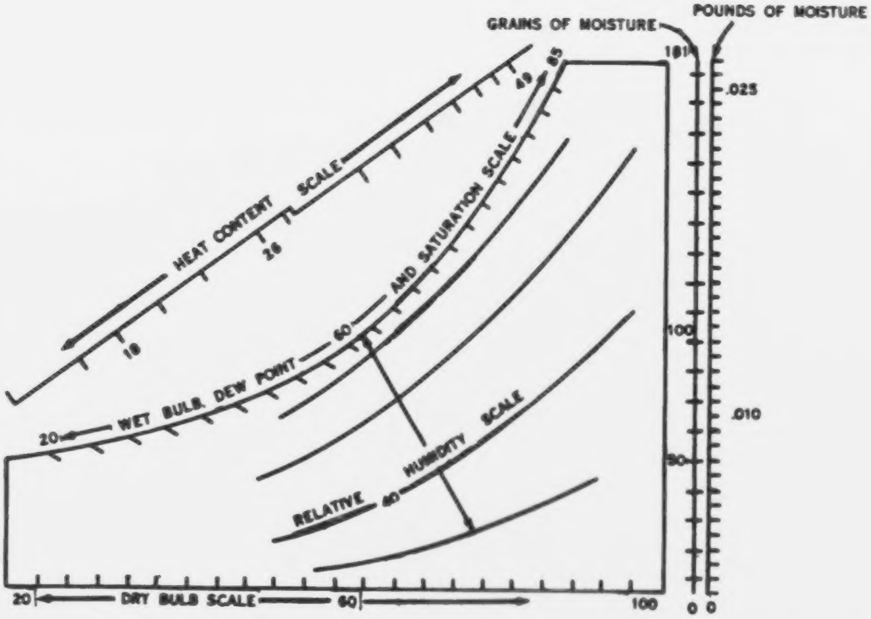

GRAINS OF MOISTURE
POUNDS OF MOISTURE
HEAT CONTENT SCALE
18
28
49
WET BULB, DEW POINT AND SATURATION SCALE
20
60
85
RELATIVE HUMIDITY SCALE
40
DRY BULB SCALE
20
60
100
181
100
50
0
0
.025
.010

Fig 5-1. Psychrometric chart scales.

The DRY-BULB will appear on the vertical lines of the chart which corresponds to the dry-bulb scale located along the bottom of the graph. Dry-bulb temperature is plotted by locating the indicated condition on the scale and drawing a vertical line corresponding to the temperature valve, as shown by the heavy line in figure 5-2.

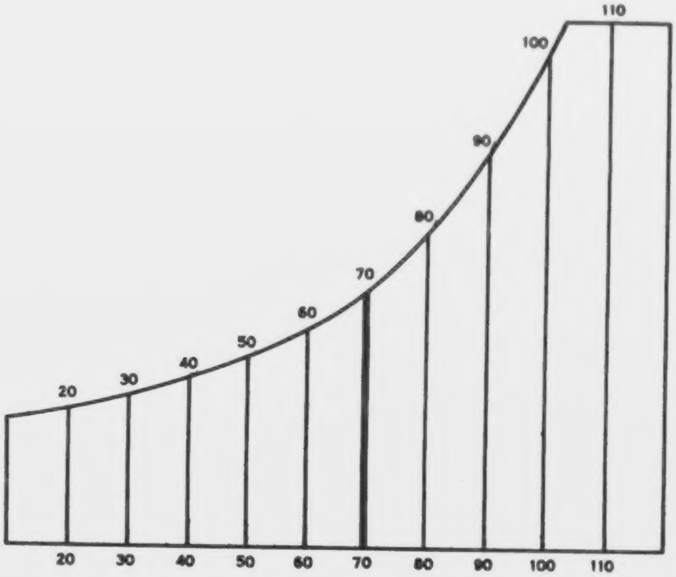

20
30
40
50
60
70
80
90
100
110
20
30
40
50
60
70
80
90
100
110

Fig 5-2. Dry-bulb line.

Figure 5-2 is a representative sketch of the dry-bulb temperature portion of a psychrometric chart. A complete psychrometric chart has a vertical line for each degree of temperature. Usually, every fifth line is numbered with its corresponding temperature. The common range for a psychrometric chart is from about 20° to 105° F. This type of arrangement makes it simple to plot any dry-bulb temperature on the chart to the nearest degree.

You will notice that the slope of the psychrometric chart changes to smaller increments as the temperature drops in intensity. The wet-bulb temperature is plotted from the temperature values given on the saturation or wet-bulb scale. To plot a WET-BULB TEMPERATURE, start with the corresponding temperature reading on the wet-bulb scale. The wet-bulb temperature is plotted on the diagonal line that extends to the right and downward from the wet-bulb scale. A wet-bulb plot is shown by the heavy line in figure 5-3. It is not necessary to extend the wet-bulb line past its intersection with a previously plotted dry-bulb line.

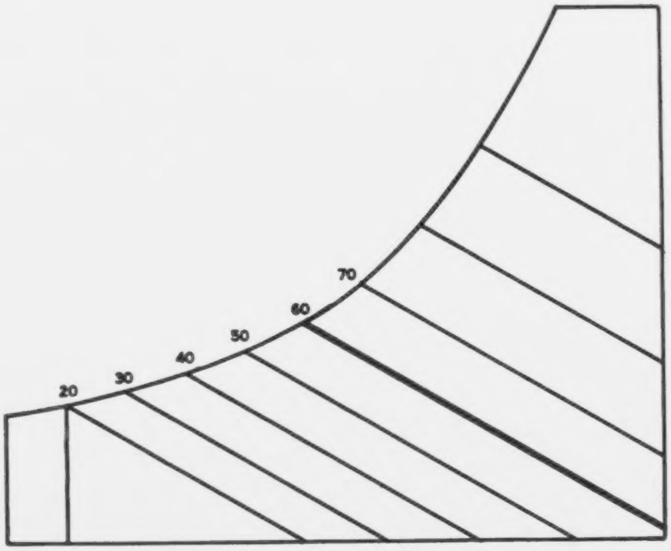


Fig 5-3. Wet-bulb line.

RELATIVE HUMIDITY is read on the psychrometric chart at the point of intersection of the dry-bulb lines, as seen in figure 5-4.

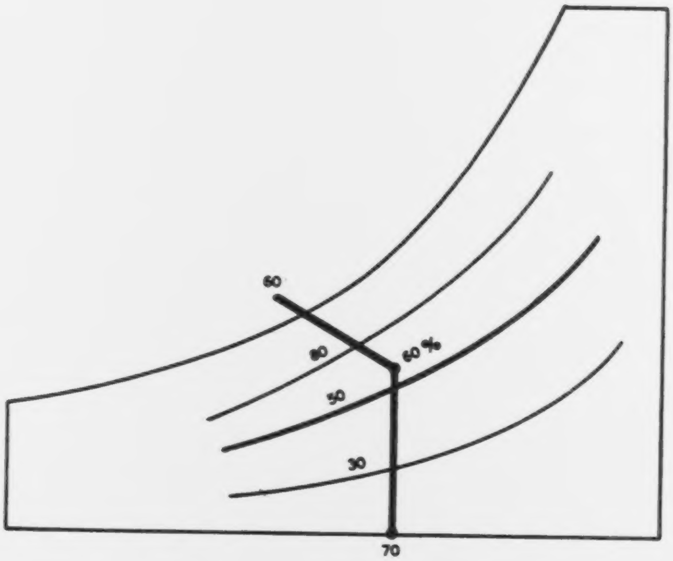


Fig 5-4. Percent relative humidity.

The DEW-POINT on the horizontal line of the psychrometric chart that extends from the point of percent relative humidity to the saturation curve, and the value is read at the point of intersection with the curve, as shown in figure 5-5.

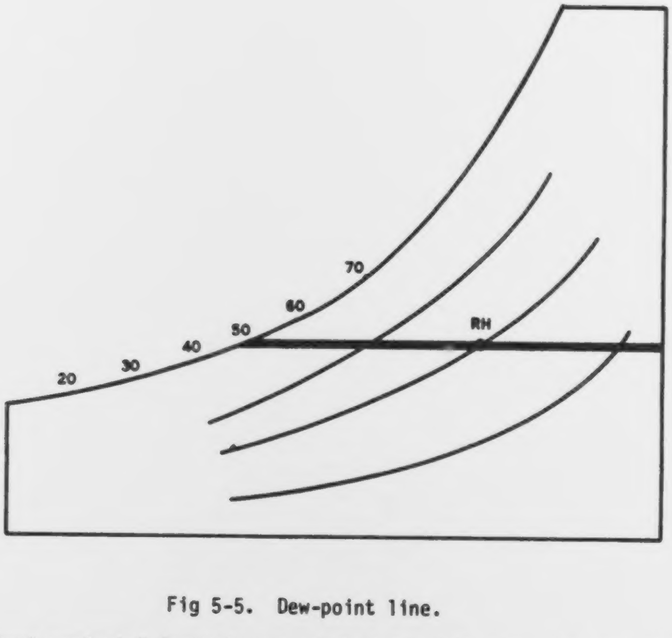


Fig 5-5. Dew-point line.

The terms "heat content," "enthalpy," and "total heat", mean the same thing. These are all measures of the Btu's contained in 1 pound of dry air. HEAT CONTENT is plotted by extending the wet-bulb line through the saturation curve to the heat content or enthalpy scale, located on the left of the saturation scale. Read the Btu value at the point the extended wet-bulb line intersects the heat content scale, as shown in figure 5-6.

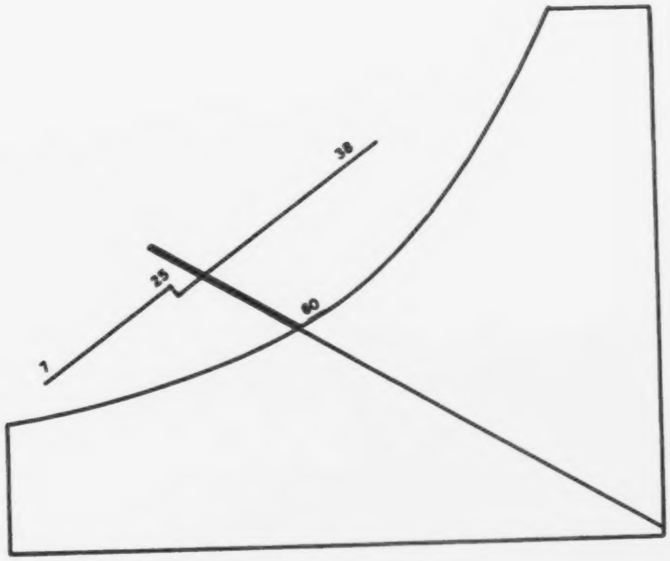


Fig 5-6. Heat content line.

To plot GRAINS OF MOISTURE contained per pound, draw a horizontal line from the point percent relative humidity to the grains of moisture scale and read the intersecting value on the chart as shown in figure 5-7.

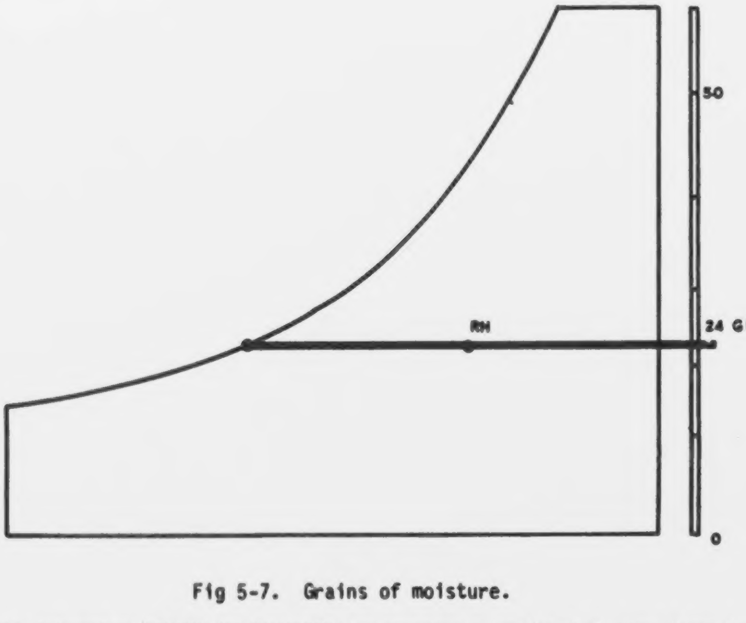


Fig 5-7. Grains of moisture.

You would determine POUNDS OF MOISTURE by drawing a horizontal line from the grains of moisture plot to the pounds of moisture scale and reading the corresponding value at the point of intersection with the scale, as shown in figure 5-8.

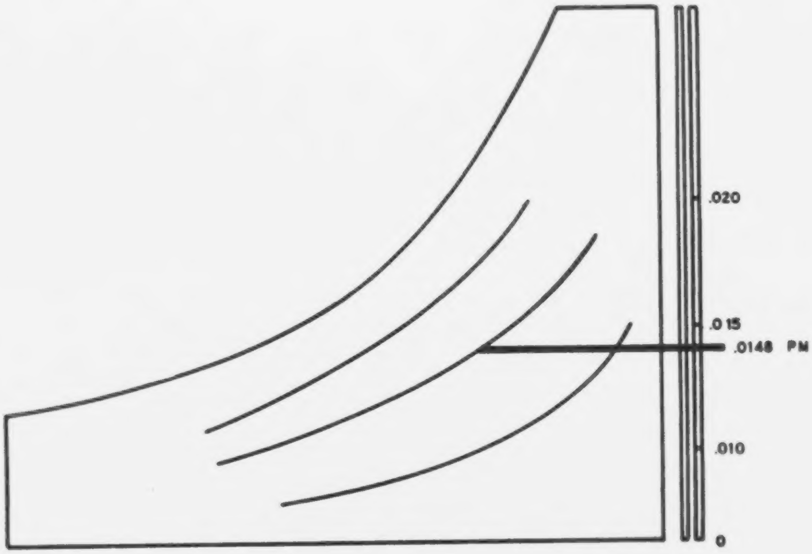


Fig 5-8. Pounds of moisture line.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. How does an air-conditioning system provide de-humidification?

2. What is the relationship between water vapor and air temperature?

3. How will an increase in air temperature affect its capacity to hold moisture?

4. Define the following terms used in air-conditioning:
    a. Specific heat -
    b. Wet-bulb -
    c. Wet-bulb depression -
    d. Grains of moisture -

5. What is the condition of the air when the temperature of the dry-bulb, wet-bulb, and dew-point are all the same?

6. Using the fold-out of the psychrometric chart found at the end of this study unit, determine the following properties of air if the dry-bulb temperature reading is 87° F and the wet-bulb temperature reading is 73° F.

   a. What is the relative humidity?

   ____

   b. What is the dew-point temperature?

   ____

   c. What is the heat content?

   ____

   d. How many grains of moisture are contained in the air sample?

   ____

   e. How many pounds of moisture are contained in the air sample?

   ____

7. What does a complete psychrometric chart have for each degree of temperature?

   ____

8. What is the purpose of the psychrometric chart?

   ____

9. How do you read the lines and curves of the psychrometric scale?

   ____

Work Unit 5-2. AIR FLOW INSTRUMENTS

GIVE THE PURPOSE AND SELECTED USES OF THE ANEMOMETER.

STATE THE PURPOSE OF THE MANOMETER AND THE PITOT TUBE AND ONE CHARACTERISTIC OF THE MANOMETER.

SUPPLY THE PURPOSE AND SIGNIFICANT CHARACTERISTIC OF THE VELOMETER.

Air-conditioning systems are designed to condition the air within the system and then to distribute this treated air to the proper place, in the proper amounts, and with the least possible annoyance to the consumer of the conditioned air.

This work unit will acquaint you with various types of air measuring instruments.

The ANEMOMETER is an instrument used to measure air velocity in linear feet. This meter is composed of the fan housing, three dial faces, and the propeller, which moves at the rate of the airspeed, turning a gear mechanism which operates the dials. There is an engaging level and a reset lever on top of the dial face. All of this is seen in figure 5-9.

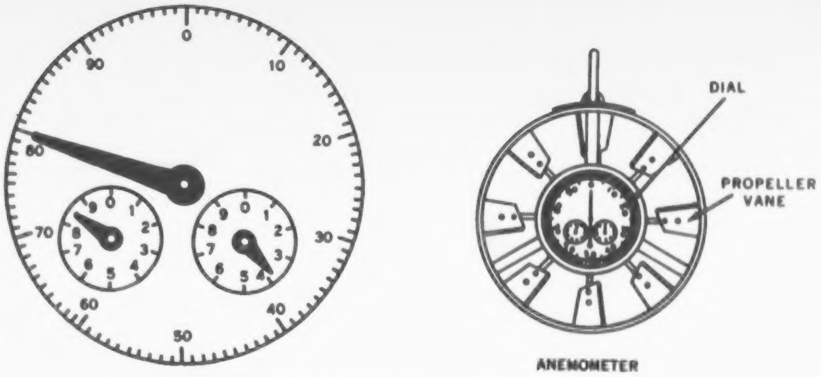


Fig 5-9. Anemometer reading.

In using the anemometer, you normally take readings at the duct face. The face should be divided into equal 6-inch squares. If the duct measured 24 X 18 inches, then there would be four 6-inch squares across the length, and three 6-inch squares across the height, or a total of 4 X 3 = 12 equal inch squares of surface area. This can be seen in figure 5-10.

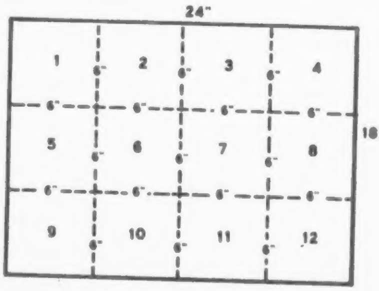


Fig 5-10. Calculating duct surface area.

At each of these 6-inch openings, the anemometer will be used for 10 seconds. The resulting time lapse for the total measurement is expressed as "elapsed time", and it is obtained by multiplying the number of equal 6-inch squares by 10. For example: 12 X 10 = 120 seconds.

To operate the anemometer, place the instrument into the stream of air being measured. Before starting, check to be sure that your hands are cupped around the meter in such a way as to prevent obstructing the air-flow through the meter. Allow the propeller to reach maximum speed, trip the engaging lever and hold it in the same location for 10 seconds, then move to the next area(s) until all of the 6-inch areas have been measured, and trip the lever to the OFF position.

In reading the anemometer, suppose you held the instrument in the air-stream for 120 seconds. In this case, the reading on the dials would be read in the following sequence:

- Left dial reading
- Right dial reading
- Center dial reading

If the indicator on the two smaller dials is between any two numbers, take the reading of the lesser number and read the large dial exactly as indicated. Study figure 5-9 accurately to understand the reading.

In figure 5-9, the left dial reading would be 8,000, the right dial reading would be 300, and the center dial reading would be 80. Therefore, combining the numbers into proper sequence, the resulting anemometer reading would be 8380.

The following formula is used to convert the anemometer reading to fpm velocity:

$$\text{fpm} = \frac{\text{anemometer reading (AR) X 60}}{\text{elapsed time (ET)}}$$

To figure the fpm of our sample problem, the answer would be:

$$\text{fpm} = \frac{\text{AR X 60}}{\text{ET}} = \frac{\text{8380 X 60}}{120} = \frac{8380}{2} = 4{,}190$$

The MANOMETER family of air measuring instrument contains various types and styles; however, we will limit the study of manometers to one type, the INCLINED MANOMETER. This is used to measure the pressure of air in inches of water and can be seen in figure 5-11.

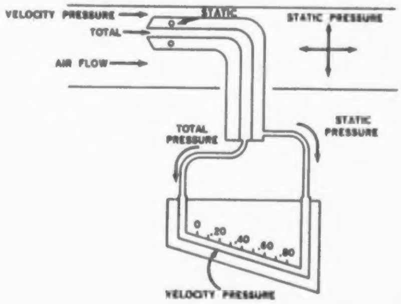


Fig 5-11. Pitot tube and manometer.

Within the duct system we find two predominant pressures; static and velocity. STATIC PRESSURE is the outward pressure of air in all directions. VELOCITY PRESSURE is the force exerted by the movement of air in the direction of flow. Often it is impossible to get the manometer into the air-stream to measure the pressure, so the PITOT TUBE was developed to allow access to the internal sections of the duct in hard to get to areas. In reality, the pitot tube is a tube within a tube, as indicated in figure 5-11.

The pitot tube is inserted into the air stream, and the velocity pressure goes into the center of the assembly to the manometer, forcing the oil column in the meter downward.

The static pressure enters the small ports surrounding the tube to the manometer, forcing the column of oil in the meter tube upward. The velocity reading is taken on the adjustable scale where the oil level stabilizes.

The pressure indicated on the manometer is known as pressure of velocity. It is represented as PV in the conversion formula used to convert pressure into feet per minute. To convert pressure of velocity into fpm, the following formulas will be applied:

$\text{fpm} = \text{PV X 4,005}$

fpm - The number of feet of air which will pass through a duct area in 1 minute.

$\sqrt{}$ - Symbolizes square root

$\sqrt{\text{PV}}$ - Pressure of velocity as read on the inclined manometer.

X - Multiplied by.

4,005 - This a constant and is based on the velocity of standard air.

Now, let's see how the formula works. Assume that the velocity pressure reading or .25 has been obtained with the manometer. Then: fpm = the square root of .25 X 4,005 = .5 X 4,005 = 2,002.5.

The VELOMETER is a rugged mechanical system, one soundly engineered for very concise readings. Inside the meter, air impinges on an aluminum vane, moving the pointer. This vane travels in a calibrated air chamber or tunnel constructed to be airtight in order to provide a desirable scale distribution. The moving system is balanced by counterweights to provide accuracy in all positions. This moving system is equipped with bronze hairsprings and moves metal pivots, which ride in sapphire jewel bearings. Some velometers are equipped with filters to protect them from extreme dusty conditions. When a filter is supplied with the instrument, the filter is an integral part of the instrument and must be used. If the filter is omitted, the instrument will give a false reading.

To measure velocities at supply openings, attach the proper jet by means of the appropriate tube and tube fittings. To determine the average velocity, mentally divide the opening into equal areas. Take a reading at each of the areas and average the readings. There is no exact rule for the number of readings that must be taken, but the more that are taken, the more accurate the average. It is recommended that a minimum of six readings be used.

To measure the air velocity at the suction opening, connect the proper jet by means of the tube and tube fittings to the right-hand port of the meter. While taking the readings, hold the jet so that it is perpendicular to the suction openings and the tip is in the same plane as the opening. This is very important because the velocity changes very quickly in front of a suction opening. To measure velocities inside ducts, use the duct jet called for in the manual of instructions. The duct jet should be inserted into the left-hand port. Read the scale marked with the same number of jets being used.

After establishing the fpm, the cfm can be established using the following formula:

cfm = fpm X duct area (sq. ft.)

Once the cfm has been established, you can calculate the pounds of air changed per minute in the space being considered. Thus:

$$\text{lbs of air} = \frac{\text{cfm}}{\text{specific volume}} \quad \text{or cfm X specific density}$$

Note: REMEMBER: IF NO MEANS ARE PROVIDED FOR FINDING SPECIFIC VOLUME, USE THE VALUE FOR STANDARD AIR, WHICH IS 13.5 CUBIC FEET. SPECIFIC DENSITY FOR STANDARD AIR IS 0.75.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the purpose of the anemometer?

____

____

2. How long a time should the anemometer be held in one location?

____

3. What is done before you trip the engaging lever on the anemometer?

____

4. What sequence would you follow when reading the dials on the anemometer?

____

5. What is the purpose of the manometer?

____

____

6. What pressure is indicated on the manometer?

____

7. What is the purpose of the pitot tube?

____

____

8. What is the purpose of the velometer?

____

____

9. Explain the importance of using the filter in the velometer?

____

____

10. How many readings should you take at the supply opening ?

____

Work Unit 5-3. INSTALLATION OF AIR-CONDITIONING EQUIPMENT

PROVIDE SELECTED INSTALLATION PROCEDURES FOR WINDOW AIR-CONDITIONERS.

CITE SELECTED INSTALLATION PROCEDURES FOR EVAPORATIVE COOLERS.

SUPPLY SELECTED INSTALLATION REQUIREMENTS FOR FLOOR-MOUNTED AND CENTRAL AIR-CONDITIONER UNITS.

Installation and operation procedures for each air-conditioning unit will vary due to the variation in design and size. Only those skilled and fully checked out in the procedures and operation of air-conditioning equipment should attempt to engage in this work. Many thousands of dollars have been tied up in the procurement of equipment. Don't let it go to waste by allowing inexperienced personnel to use it.

Window units should always be installed with the outside portion of the unit tilted down slightly, as shown in figure 5-12. This slight tilt, about 1/4 inch, helps drain the condensated air outside, rather than letting it overflow inside the space being conditioned

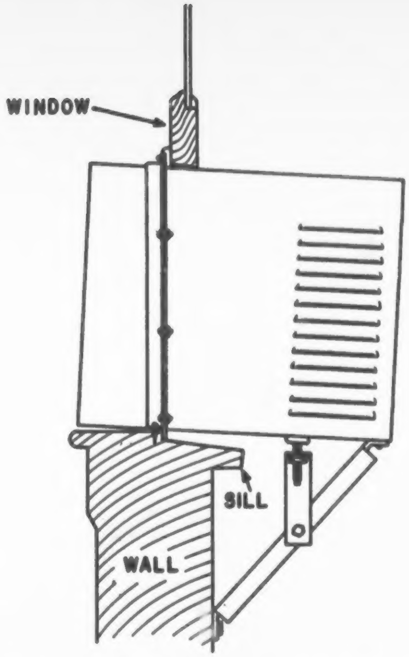

WINDOW
SILL
WALL

Fig 5-12. Window unit showing 1/4 inch tilt.

Normally all of the hardware needed to install the unit will be in the shipping container, as shown in figure 5-13. Also, brackets for holding the unit housing in place are enclosed.

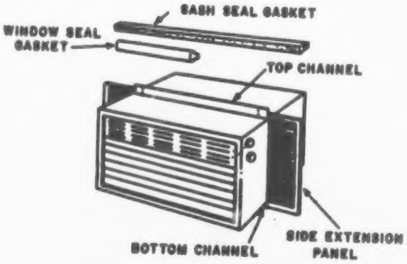

SASH SEAL GASKET
WINDOW SEAL GASKET
TOP CHANNEL
BOTTOM CHANNEL
SIDE EXTENSION PANEL

Fig 5-13. Window unit with necessary hardware for installation.

Many mounting designs are available for particular applications or window-mounted air conditioners. A few of the various mounting's are:

- Inside flush mounting. The interior face of the conditioner is approximately flush with the inside edge of the window sill.
- Balance mounting. The unit is installed approximately half inside, and half outside the window.
- Outside flush mounting. The outer face of the unit is flush or slightly beyond the outside wall.

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- All-in-mounting. The unit is completely inside the room, so that the window can be closed.
- Upper sash mounting. The unit is mounted in the top of the window.
- Built-in mounts. The mounts are used for installing units in the walls of hotels, motels, and residences, etc.

The housing should be securely mounted before the unit is installed. The side panels are usually sealed to the window with sponge rubber and sealing compound. Sheet metal screws are used to secure the top and bottom channels. For the foregoing, look at figure 5-14.

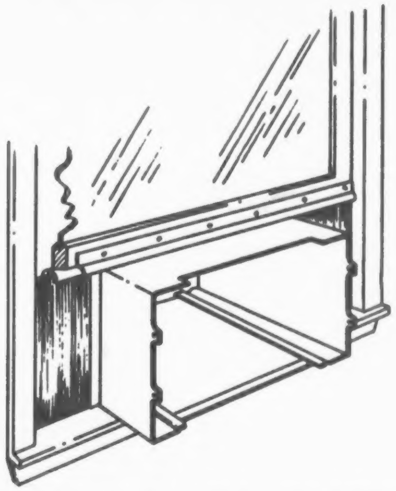


Fig 5-14. Window unit housing installed.

The inside unit is quite heavy and should not be lifted without the assistance of another person or the use of a special dolly. Carrying the unit by means of the refrigerant lines or coils should be avoided completely. If a special dolly cannot be used for transporting the unit or is not available, then place your hands on the bottom of the unit to lift it.

When putting the unit into the housing, be careful not to force the unit. If you force the unit, the tubing and wiring can be pinched between the unit and casing.

The current draw on start-up is sufficient to justify the need of these units being placed on a separate circuit. REMEMBER, because of this current, a plug with a ground wire should always be used.

Long before the refrigeration coil became the basis of air-conditioned comfort, EVAPORATIVE COOLERS and COOLING SYSTEMS were used to some extent in semiarid and arid states such as Kansas, Colorado, and New Mexico, for example, where the daily humidity was usually very low. Even today, bases located in dry climates employ this type of cooling with considerable success at a low cost.

The small units, although usually mounted in the window of a building (side draft type), can also be mounted on the roof (down draft type). The larger units must be placed on substantial structures that will support their weight.

The size and style of the unit determines the location and the type of supporting structure required.

Units mounted in building windows are of the small blower type. These are light in weight and will not damage the building structure. This type is shown in figure 5-15.

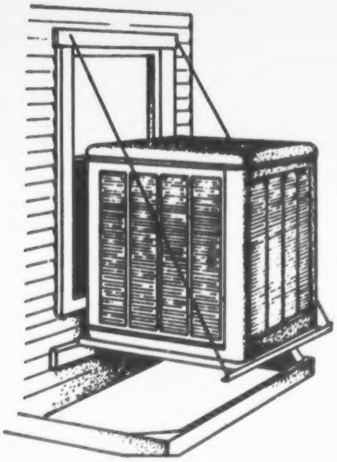


Fig 5-15. Evaporative cooler.

The large, heavy units must be mounted on self-supporting platforms adjacent to, but independent of the building, as seen in figure 5-16. In some cases, it may be more economical to mount the unit on a cement platform such as with the airwasher-type units.

The dimensions and operating weight of the cooler should be determined before construction is started on the supporting structure or mounting platform. A walkway with guardrails around the cooler should be provided for the safety of the maintenance personnel and to give them proper access to the equipment when making repairs, as seen in figure 5-16. Each platform should also have a ladder built as part of the structure.

Never mount cooler units on the building roof unless approved. Each unit must be mounted on the platform, so that it is rigid and level. In some cases, the use of shims and bolting down the unit is necessary. As an aid, every cooler manufacturer furnishes mounting and installation instructions with each type of unit it makes. Therefore, those personnel assigned to mount cooler units should read the instructions carefully before they proceed to mount the units.

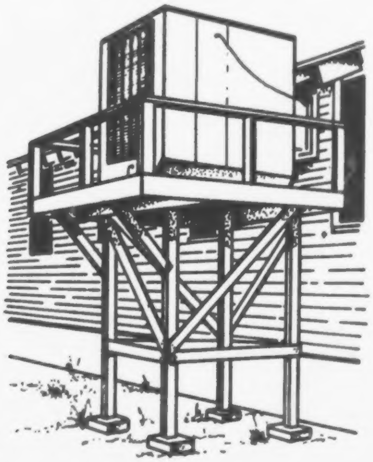


Fig 5-16. Large evaporative cooler mounted on self-supporting platform.

The various connections required for evaporative coolers must be installed as specified for each cooler. Check the instructions to see that the proper size pipe, valves, switches, wire, and fuse boxes are installed. Only in this way can you be sure that the equipment will give the expected service.

The small, window-type evaporative cooler normally uses 1/4 inch copper tubing to carry the water supply. A fitting is installed on any ordinary 3/4 outside water valve (garden hose) to supply the water.

Larger units must have a water supply line of at least 3/4 inch pipe or tubing. A globe shut-off valve should be installed in the supply line on the inlet side of the unit. Coolers using a water solenoid valve instead of a recirculating pump should have a water strainer installed on the inlet side of the solenoid valve. A water faucet with a hose bib should be installed in the supply line near the cooler to be used in washing down the interior of the evaporative coolers immediately after dust storms or when maintenance service is being done.

The water drain or waste system for evaporative coolers ought to be at least 1-1/4 inches in diameter to reduce drain stoppage. The drain system should be connected to the sewer or a street drainage system. In freezing areas, the water supply system should be insulated against freezing, or the unit may be installed to permit the complete draining of the system.

Small units (window type) are usually connected by inserting the electric cord plug into a convenient outlet. Thus, they can be placed into or out of operation by means of a toggle switch on the front of the unit.

The larger units should be equipped with their own fuses. Sometimes this may require a separate main switch and fuse box, depending upon the power requirements of the unit(s). Push-button stations or toggle switches are used to start and stop equipment operation. Other units may require separate switches for the water recirculating pump motor and the blower motor. Usually the larger units require magnetic starters also, sometimes they have pilot lights or other devices to indicate when and what part of the cooling unit is in operation. All switches, controls, pilot lights, and indicators should be mounted on a control panel which is located in a convenient place. Each large evaporative cooler should have a disconnect switch mounted inside the unit to permit maintenance personnel to control the unit's operation while they are performing maintenance service. This is a timesaving move as well as a safety measure.

In FLOOR-MOUNTED AIR CONDITIONERS, the whole system is mounted in one cabinet. Usually, the only thing that needs to be done to this unit is to hook up the power and level the unit as shown in figure 5-17.

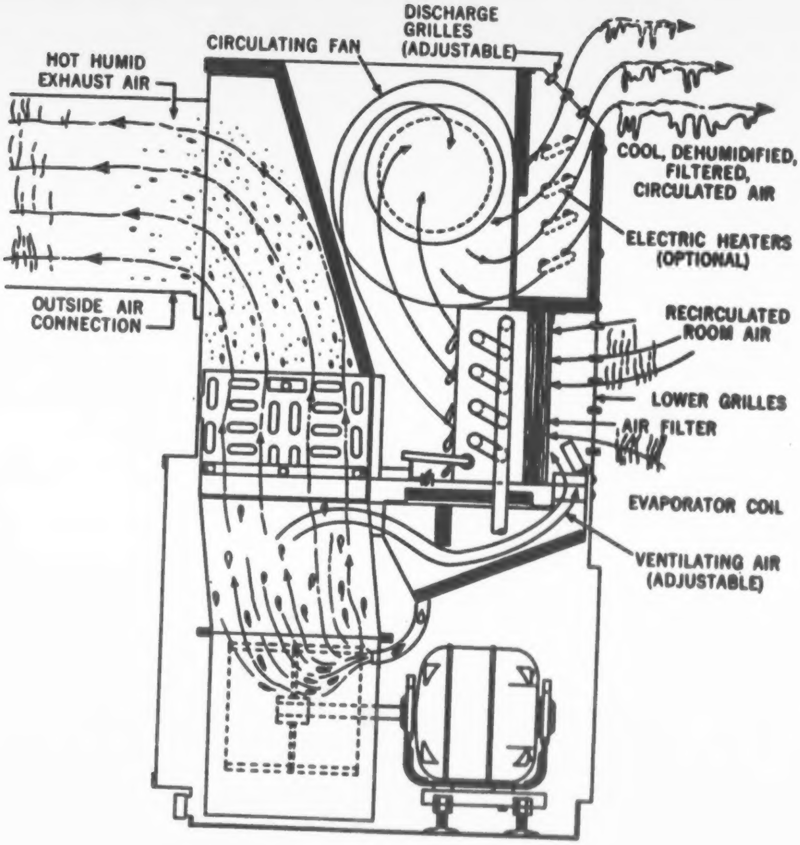

DISCHARGE GRILLES (ADJUSTABLE)
CIRCULATING FAN
HOT HUMID EXHAUST AIR
COOL, DEHUMIDIFIED, FILTERED, CIRCULATED AIR
ELECTRIC HEATERS (OPTIONAL)
OUTSIDE AIR CONNECTION
RECIRCULATED ROOM AIR
LOWER GRILLES
AIR FILTER
EVAPORATOR COIL
VENTILATING AIR (ADJUSTABLE)

Fig 5-17. Sectional view of a floor mounted air-conditioner.

Floor models may have either air-cooled or water-cooled condensers. Of these, the air-cooled condenser may or may not be a part of the unit, while the water-cooled condenser is usually mounted outside. If the air-cooled condenser is a part of the unit, then the condenser must be ducted to the outside for condenser cooling. The water-cooled condenser sits on a level cement slab, and with the help of a circulating pump it conditions and circulates cool water to the unit.

The electrical connections should conform to local codes. Once the electrical connections have been completed, the compressor should be checked for proper current.

The CENTRAL SYSTEMS may be used for residential or industrial use. The system may be obtained in the following ways; as a whole unit or as individual components for erection at the area(s) where each will be used.

Whole units are obtained more frequently than components for assemblyare , since they come from the factory as complete units which do not require assembly. In both the evaporator and condenser, the internal piping and wiring has been completed. For the foregoing, see figure 5-18.

In almost all cases, the blower and duct work used for the existing heating system will be used to carry air across the evaporator. The evaporator is usually erected on top of the furnace body in the discharge air duct, as shown in figure 5-19.

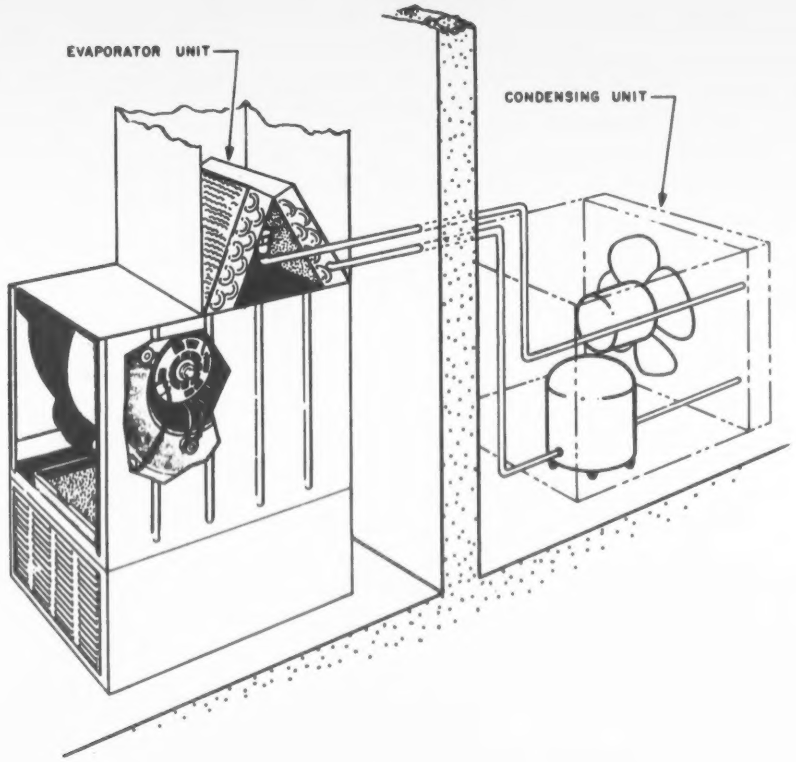

EVAPORATOR UNIT
CONDENSING UNIT

Fig 5-18. Central air-conditioner.

In almost all cases, the blower and duct work used for the existing heating system will be used to carry air across the evaporator. The evaporator is usually erected on top of the furnance body in the discharge air duct, as shown in figure 5-19.

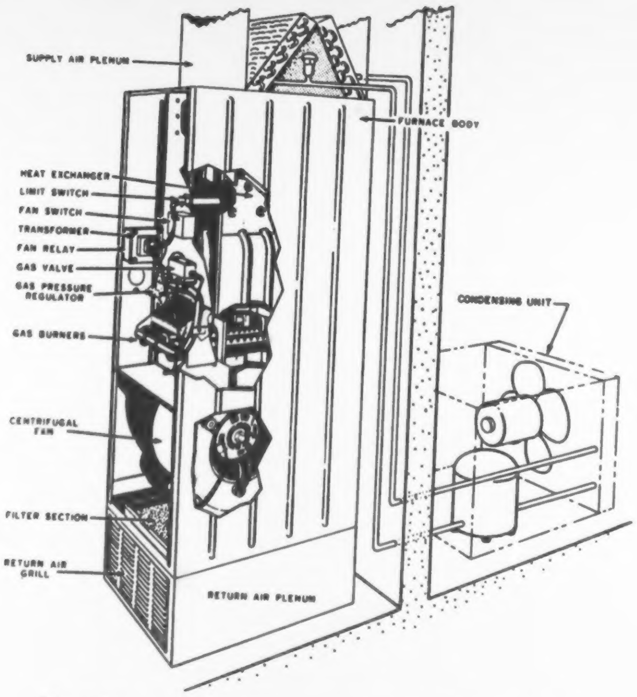

SUPPLY AIR PLENUM
FURNACE BODY
HEAT EXCHANGER
LIMIT SWITCH
FAN SWITCH
TRANSFORMER
FAN RELAY
GAS VALVE
GAS PRESSURE REGULATOR
CONDENSING UNIT
GAS BURNERS
CENTRIFUGAL FAN
FILTER SECTION
RETURN AIR GRILL
RETURN AIR PLENUM

Fig 5-19. Evaporator mounted above the furnace.

There are three different types of evaporators; the A-type, the slant type, and the flat type.

Through years of use, evaporator coils stand a good chance of getting dirty. Install access panels so that the coils can be reached for cleaning.

The evaporator drain should be piped either to the outside or to an open floor drain. A U-trap can be installed in these lines to prevent insects from crawling into the building or to keep air from blowing through the drain.

Condensing units should be installed outdoors on a level, reinforced concrete slab. The unit should be lower than the evaporator, and the suction line should slope toward the compressor to assist oil return.

A sight glass and a filter-drier should be installed in the liquid line, in the line between the receiver and the expansion valve.

The suction line, from the outlet of the evaporator to the compressor, should be insulated to keep it from sweating.

Electrical connections should be according to the particular manufacturer's wiring diagram and in accordance with the National Electrical Code.

The installation of centrifugal systems vary very little from the installation of other types of units. In a centrifugal machine, the compressor, condenser, cooler, economizer, and motor are all on the same base. The machine must be installed on a reinforced, level concrete pad. Without a level base, the machine could be damaged, and refrigerant leaks could develop from the vibration set up by the high-speed operation of the compressor. The electrical wiring should conform to the standards previously mentioned for other units.

EXERCISE: Answer the following questions and check your responses against those listed at the end of the study unit.

1. Why is it important to slightly tilt downward the air-conditioner outside of the window ?

2. A work request indicates the unit to be upper sash mounted. Where will you install the unit in relation to the window?

3. What factors determine the location and type of supporting structure required when installing evaporative coolers?

4. What is the minimum specification for the water supply line for large evaporative cooler units?

5. Why should you install a disconnect switch inside the evaporative cooler unit?

6. What is the best way to mount airwasher-type evaporative coolers and why?

7. What should be the size of the water drain or waste system in evaporative coolers and why should it be this size?

8. What must be done if the air-cooled condenser is part of the floor-mounted unit?

9. Why is a U-trap installed in the evaporative drain line?

10. If at all possible, why should you install the condensing unit lower than the evaporator in a central air-conditioner?

Work Unit 5-4. SERVICE AND MAINTENANCE OF AIR-CONDITIONING EQUIPMENT

CITE SELECTED PROCEDURES AND PRECAUTIONS RELATED TO THE BEARING INSPECTION AND LUBRICATION FOR AIR HANDLING UNITS.

STATE SELECTED PROCEDURES USED FOR CHECKING BEARINGS, BELTS, AND PULLEY ALINEMENT, AND GIVE A REASON RELATED TO THESE COMPONENTS AND THEIR ALINEMENT.

DESCRIBE SELECTED HEAT PUMP SERVICE AND MAINTENANCE PROCEDURES.

STATE THE MAINTENANCE ACTION FOR SELECTED EVAPORATIVE COOLER COMPONENTS.

IDENTIFY SPECIFIC SERVICE AND MAINTENANCE REQUIREMENTS ON SECONDARY REFRIGERANT SYSTEMS AND VALIDATE STATEMENTS ABOUT THESE SYSTEMS.

In this work unit we will discuss the service and maintenance features of typical air-conditioning equipment.

Air handling unit bearings, unless sealed, should be inspected for proper lubrication. A lack of such lubricant causes excessive wear and seizing of the bearings.

Bearings are either oiled or greased. Accordingly, general lubrication is needed. Therefore, study the following general lubricating instructions which you need to observe:

- Wipe grease fittings, grease cups, oilers, and the surrounding surfaces clean before applying lubricants.
- Clean lubrication equipment both before and after it is used.
- Operate lubricating guns carefully and in such a manner as to insure a proper distribution of the lubricants.
- Reduce lubrication intervals to compensate for abnormal operation and extreme conditions, such as high or low temperatures, prolonged periods of operation, continued operation in sand or dust, or exposure to moisture, any of which may quickly destroy the protective qualities of the lubricant. Lubrication intervals may be extended during inactive periods.
- Keep all parts not requiring lubrication clean from lubricants. Also, after every lubricating operation, remove any excess lubricant from the point of application.
- Clean out the bearing housing before filling it with lubricant whenever the need is apparent from the evidence of dirt or sludge.
- Always use the proper lubricant as required by the attached lubrication plate or, if available, the pertinent lubrication publication and/or the technical manual pertaining to the material of which the motor is a part.
- Change the grade of lubricant in accordance with the temperature ranges prescribed in the pertinent lubrication publication and/or technical manual.
- Operate the air handler immediately after lubrication to evenly distribute the lubricant.

As you perform your lubrication , you should keep the following general precautions in mind:

- Keep all lubricants (grease and oil) in closed containers.
- Store all lubricants in a clean, dry place, one which is located well away from an external heat source.
- Allow no dirt, water, or foreign material to mix with any lubricant at any time.
- DO NOT oil bearings while the air handler is running. Excess oil may spill onto the floor, creating a fire hazard as well as an electrical hazard.

- Avoid getting lubricants on rubber parts of insulation, since they will cause these materials to deteriorate.

Bearings, belts, and pulleys are all smaller components of the air handling unit, yet its continued operation depends largely upon their proper alinement with each other. These three components in this unit will be discussed in the order named.

- BEARING ALINEMENT - Some belt-driven blowers have bearings that are self-alining, while others are held in place by bolts which stabilize the bearings to the blower housing. Study figure 5-20 as you proceed through the following. The bearings usually have slots in their base for additional adjustment. Once a bearing has been adjusted, it must be checked periodically for slippage or binding, either of which can cause damage to the blower or shaft.

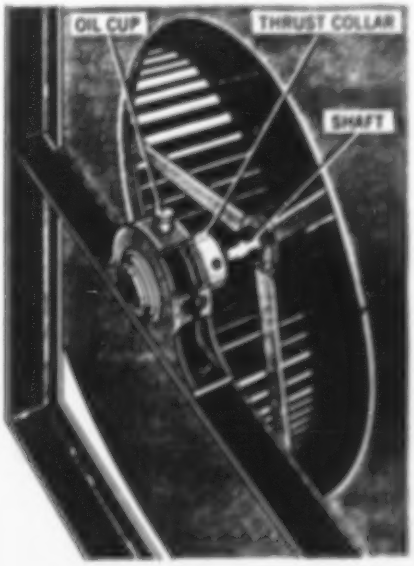


Fig 5-20. Blower bearings.

- BELT TENSION - Visual inspection of belts will tell a technician whether or not they have been tensioned properly. Thus, running belts too loose will cause them to bounce up and down or flop excessively. This, in turn, requires more tension be put on the belts. To remedy such situations, proper tension must be put on the belts, and this requires approximately a 1/2 inch depression per foot between the centers of the pulley, as shown in figure 5-21. When the unit is off, a belt check will reveal whether or not the pulleys are out of alinement; this can be determined by the excessive wear on the edge of the belts.

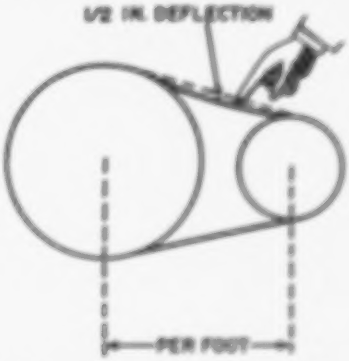


Fig 5-21. Blower belt tension.

- PULLEY ALINEMENT - Pulley alinement is very important, since the pulley transmits power by means of a band, belt, cord, rope, or chain. Bad alinement would cause these components to wear and eventually bring about unit breakdown. Improper belt alinement will also cause excessive bearing wear and possible early failure.

Both the blower and motor pulley should be placed on their respective shafts at the same time. One of the two pulleys may be secured at this time. Then, (1) a straightedge may be placed in the two pulley grooves, so that you can sight along its edge for proper alinement; (2) a string may be placed in the same manner as the straightedge; (3) a belt may be put on the pulley, and you can sight along it. Once you are satisfied that the two pulleys are in line with one another, the other pulley may be secured. After this adjustment, tighten the belts, start the motor, and observe the unit's operation until you are sure that your adjustment is correct.

The heat pump is similar to other refrigeration units. Therefore, the service and maintenance techniques vary little from those used on other refrigerating systems.

Normal service requires that the supply voltage be checked to insure correct voltage. A 1/3 to 1 ton unit usually requires a single-phase 240 volt connection; whereas, units over 1 ton normally require 3 phase, 240 volts. The electrical section of the unit should be consulted for variations of these voltages so that proper maintenance can be conducted.

Motor and refrigeration controls should be checked for proper action. Rough contacts should be cleaned to prevent arcing. Sticking controls should be checked and cleaned or lubricated to correct problem.

Lint and other foreign particles are a continuing problem for evaporators. Consequently, service personnel should check often for this situation and clean the evaporator by either soap and water or air pressure. REMEMBER, severe air pressure can damage the aluminum fins on the coils.

The reversing valve can be checked by operating the heat pump on both the heating cycle and then the cooling cycle. If the valve is not operating correctly, then replace the valve.

During low temperature operating periods, liquid refrigerant can build up in the compressor crankcase. Service personnel should check the crankcase heater for operation in order to protect the compressor. A simple ohmmeter check will tell the technician if he has a complete circuit through the heater.

Freeze-up of the outside coil (condenser) is always a concern to the maintenance personnel. To prevent freeze-up of the outside coil a defrost thermostat is installed on the unit to switch the coils long enough to change the temperature of the outside coil and thus prevent freeze-up. On misty days, when the ambient temperature outside is 32° to 100° F, the unit will spend almost equal time in the heating and defrost cycles.

Filter pads should be maintained in as clean a condition as possible for maximum effectiveness. This maintenance is accomplished by washing the pads to remove algae, water solids, and other deposits of foreign matter that will accumulate. Use a garden hose with an adjustable nozzle to wash filter pads. After the pads have been washed thoroughly, wash all loose foreign materials from the water collecting tank through the drain connection. Inspect the pads for thick sections of filter material after the washing. If a pad cannot be cleaned adequately, or if the thin layer cannot be corrected by fluffing the fibers from the adjacent thick sections, replace the pad with a new one. Normally, it is better to replace drip pads twice each cooling season rather than to try to prolong their use by special cleaning methods.

Spray pads usually last a complete cooling season, because continuous washing of the pads reduces the deposits of water solids, dust, and growth of algae on glass fiber surfaces.

Spun glass fibers accumulate water solids, which form an incrustation around the fibers and reduce their effectiveness in maintaining an affinity for water. When excessive dirt and solids accumulate on the fibers, the pads should be replaced. The sagging of glass fibers in the spray pads, particularly at the top sections, also necessitates the replacement of the pads. Since the fibers are enclosed in a wire mesh, they cannot be fluffed to obtain uniform sectional thickness.

The pad frame and the retaining screens should be wirebrushed to remove dirt and scale and then painted with rust resistant paint. Screen eliminators made of layers of wire screen should be cleaned and painted whenever excessive dirt, scale, or rust accumulate on them.

Proper water distribution and thoroughly saturated pads are essential to maximum efficiency from an evaporative air cooling unit. Drip distributors admit water to the top of the pad surface at a rate sufficient to wet the entire pad. Streams of water should flow down the outside pad surface. Level the water trough, so that approximately the same number of drops of water fall from the weir along the entire length of the trough. The troughs are usually slotted, so that they can be leveled, as shown in figure 5-22. Troughs and weirs should be cleaned by wirebrushing and re-painted with rust-resistant paint. The piping system should be disassembled and wire brushed internally whenever excessive scale formation starts to retard the water flow.

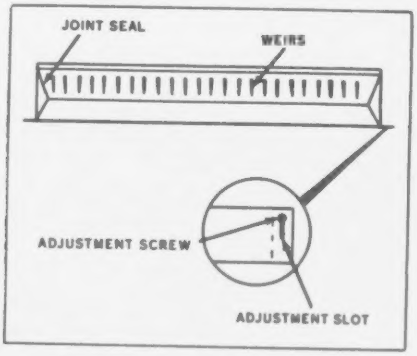


Fig 5-22. Weirs adjustments.

Spray nozzles are designed to provide sufficient water to wash the pads and form an effective spray curtain at the entrance of air stream, as pictured in figure 5-23. Spray from each nozzle or jet must have a well defined pattern. Spray nozzles should be cleaned by reaming out the openings. Slot jets may be cleaned by means of a thin blade made to fit the slot. Be very careful when you are cleaning the openings and slots in order to prevent cutting their metal edges and ruining them.

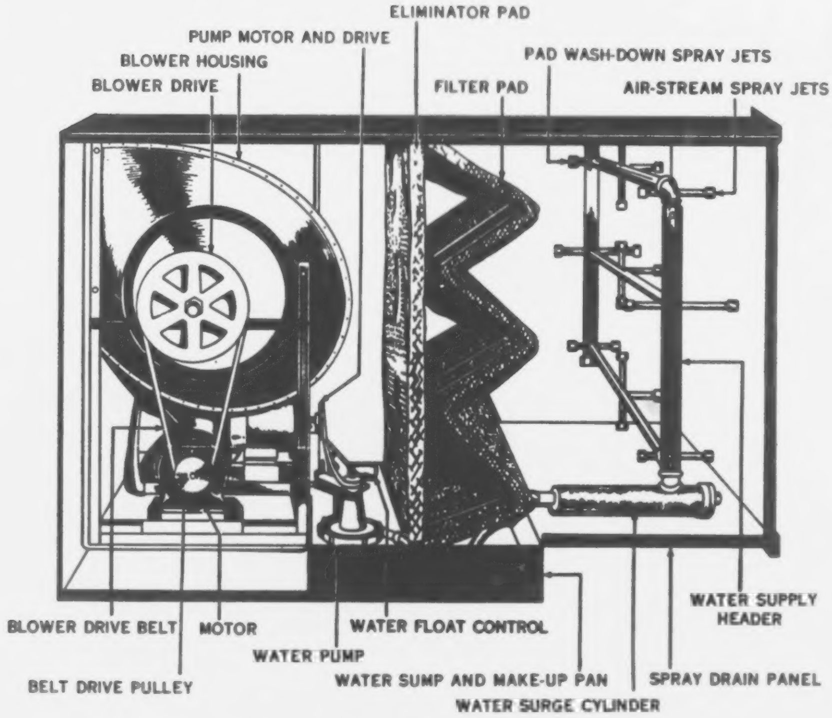

ELIMINATOR PAD
PUMP MOTOR AND DRIVE
BLOWER HOUSING
BLOWER DRIVE
PAD WASH-DOWN SPRAY JETS
FILTER PAD
AIR-STREAM SPRAY JETS
WATER SUPPLY HEADER
BLOWER DRIVE BELT
MOTOR
WATER FLOAT CONTROL
WATER PUMP
BELT DRIVE PULLEY
WATER SUMP AND MAKE-UP PAN
SPRAY DRAIN PANEL
WATER SURGE CYLINDER

Fig 5-23. Spray nozzle evaporative cooler.

You should check rotary disk water distributors for freedom of shaft rotation, and then you should lubricate them as portrayed in figure 5-24. The surface of the disk should be wirebrushed to remove the scale that has accumulated. Check the position of the water supply pipe in relation to the disk carefully. Adjust its position and lock it at the exact location recommended by the manufacturer to insure a maximum washing and spray effect. Spray nozzles, jets, and rotary disks which cannot be cleaned satisfactorily by wire brushing should be removed and cleaned by immersion in a 10% inhibited commercial hydrochloric (muriate acid) solution.

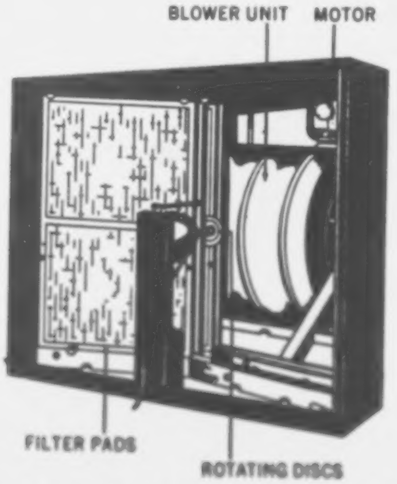

BLOWER UNIT
MOTOR
FILTER PADS
ROTATING DISCS

Fig 5-24. Rotating disc evaporative cooler.

Water pressure at the spray nozzles and jets varies with the different units. The water pressure may usually be checked at the pump discharge outlet by attaching a pressure gage to the fitting provided for this purpose. The pump discharge pressure for effective water spray and atomization should be maintained at the value recommended by the manufacturer.

The water makeup float valve should be checked for freedom of movement, and any binding of the float lever should be corrected. The water valve should be checked for positive water cutoff, since its position determines the proper water operating level. If an adjustment is required, raise or lower the float-ball position with respect to the lever pivot, as seen in figure 5-25. Set the water level to permit a constant overflow for bleed-off into the overflow stand pipe. Turn the wing nut on the adjustment screw slightly in place to insure that the float-ball lever is locked into position. Replace float balls made of ferrous metal which are rusted with float balls made of non-ferrous metal or of plastic materials.

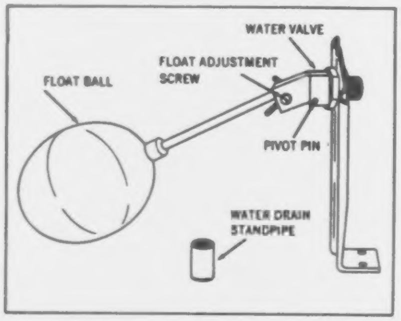


Fig 5-25. Water makeup valve and standpipe.

Because of the light construction of the water circulating pumps used with evaporative drip units, they must be carefully maintained. The low oil capacity of the bearings on the motor requires frequent addition of the correct grade of oil. If the oil does not flow readily into the oil filler tubes, remove and clean them. If the stoppage appears to be in the bearings, remove the entire pump assembly and wash the bearings out and then fill them with the proper amount of oil. Clean the impeller and interior of the casing of excessive scale by wirebrushing. Adjust the pump shaft and impeller to avoid its binding against the water intake opening or pump casing. Wirebrush and re paint rusted surfaces with rust resistant paint. When repairs are required, pumps of this type are usually taken to the shop to facilitate the service work. Sufficient replacement pump assemblies should be made available for the exchange of pumps requiring repairs.

Wire brush the exterior surfaces of the cabinet and water makeup tank, which develop rust spots, and give them a coat of rust-resistant paint. After wire brushing and cleaning the rusted areas, paint the panel interior surfaces with asphalt-base paint. You should paint the interior surfaces of both of the panels forming the water spray chamber and the interior of the water makeup tank with asphalt base paint. Wirebrush the air intake louvers and screens and clean them so that they are free of dust, insects, and scale. Straighten and repair bent or distorted vanes. Repaint metal louvers and screens as required.

Earlier, we discussed several air conditioning systems. These systems have been numerous, but little has been said about a secondary refrigerant system; therefore, the secondary refrigerant systems will be discussed in the remaining paragraphs of this work unit.

In a DIRECT EXPANSION SYSTEM, shown in figure 5-26, the controlled variable comes into direct contact with a single refrigerant source. In contrast, the INDIRECT SYSTEM, shown in figure 5-27, allows the heat from the conditioned space to be absorbed by a secondary refrigerant, water or brine, thereby cooling the variable.

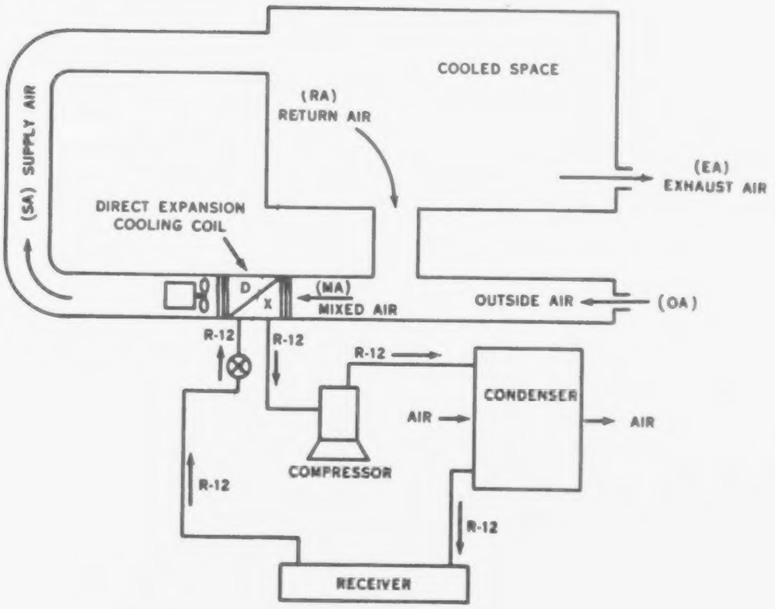

COOLED SPACE
(RA)
RETURN AIR
(SA) SUPPLY AIR
(EA)
EXHAUST AIR
DIRECT EXPANSION
COOLING COIL
D
X
(MA)
MIXED AIR
OUTSIDE AIR
(OA)
R-12
R-12
R-12
CONDENSER
AIR
AIR
COMPRESSOR
R-12
R-12
RECEIVER

Fig 5-26. Direct expansion system.

When water is used as the secondary refrigerant, the controlled variable cannot be below freezing. Thus, the water makeup tank (expansion tank) should be checked often so that enough water is kept in the system to assure a positive head at all times.

Brine solutions are used when the controlled variable must be maintained below freezing (32° F). Brine is a mixture of water with a chemical substance that allows it to be cooled to a sub-zero temperature without solidifying.

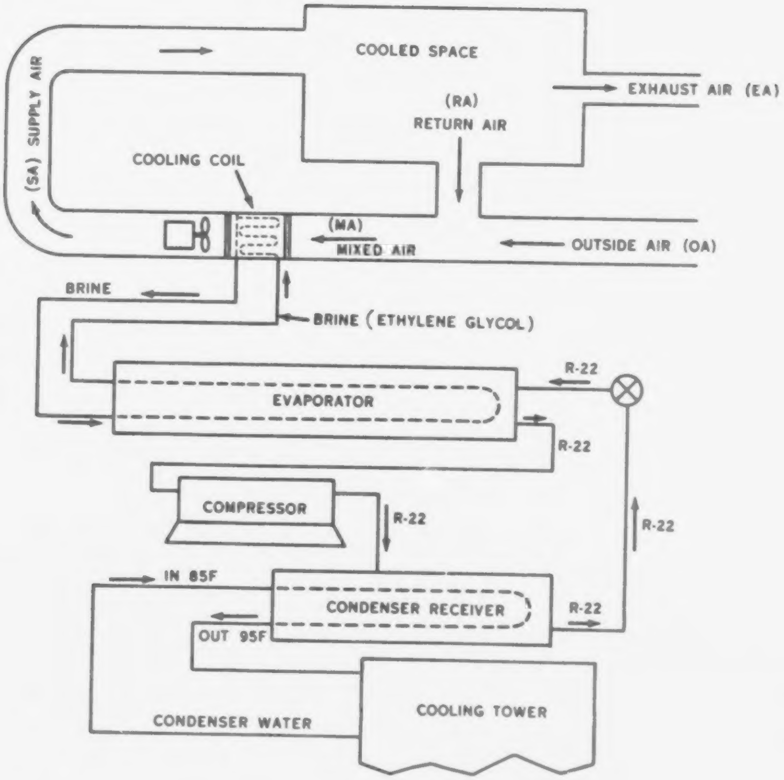

COOLED SPACE
EXHAUST AIR (EA)
(RA)
RETURN AIR
(SA) SUPPLY AIR
COOLING COIL
(MA)
MIXED AIR
OUTSIDE AIR (OA)
BRINE
BRINE (ETHYLENE GLYCOL)
R-22
EVAPORATOR
R-22
COMPRESSOR
R-22
R-22
IN 85F
CONDENSER RECEIVER
R-22
OUT 95F
COOLING TOWER
CONDENSER WATER

Fig 5-27. Indirect expansion system.

There are several types of brine; ALCOHOL, SALT, and GLYCOL. Of these, glycol brines are the most widely used, since they have noncorrosive properties.

Check the brine mixture for its density with a hydrometer. If you find that the freezing point is too high, then add more chemical. A chart from the manufacturer can give you the correct mixture of water and chemical in order to get a predetermined temperature.

It is very difficult to set up a definite maintenance schedule, since so many operational factors must be considered. Consequently, it will be necessary for you to be fully aware of the instructions within the Standing Operating Procedures for your organization and you must follow these instruction and recommendations.

The tubes on the condenser and cooler must receive regular attention for efficient performance and long life. In fact, take special care during the first year of operation because of the dirt and other foreign materials which may have collected in the system during installation. The water-treating system must operate effectively to prevent general corrosion of the tubes and piping system. Foreign material and corrosive attack can do extensive damage to the system's piping and water tubes, if they are not treated effectively and correctly.

A special type of nylon brush should be used to clean the tubes. This brush is designed to prevent scraping or scratching of the tubes' inner wall. Force the brush through each tube by hand pressure. During this cleaning process, most of the scale, mud, and other foreign deposits will be loosened. You can remove all such loose deposits by flushing the surfaces with water.

If the tubes have become completely covered with scale, you must use a chemical treating process to remove all foreign deposits. The manufacturer's maintenance manual will give you information about the type and strength of chemical solutions to use on their designed units.

It is recommended that the condenser tubes be brushed at least once a year. Hourly checks must be made between the difference of the leaving condenser water temperature and the condensing temperature. If at full-load operation this difference exceeds the design value, fouling of the tube surfaces is taking place. Should you discover that the leaving condenser water temperature is hard to maintain, it is recommended that you clean the condenser tubes.

The following procedures should be followed in cleaning tubes:

- Shut off the main water line inlet and outlet valves.
- Drain water from the condenser through the water box drain valve. Open the vent cock in the gage line or remove the gage to help draining
- Remove all but two nuts from the water box covers, leaving the remaining two on, loosely attached for safety.
- Using specially threaded jacking bolts, force the covers away from the flanges. As soon as the covers are loose from the gaskets, secure a rope to the rigging bolt in the covers and an overhead support. Then remove the last two nuts and place the cover on the floor.
- Scrape both the cover and the matching flange to free any gasket material.
- Remove the water box division plate by sliding it out from its grooves. Be cautious in removing this plate; it is made of cast iron, which can break easily. Penetrating oil may be used to help remove the plate.
- Use a nylon brush or something similar on the end of a long rod. Clean each tube with a scrubbing motion and flush each tube after the brushing has been completed.
- Replace the division plate after first shellacking the required round rubber gasket in the two grooves.
- Replace the water box covers after first putting graphite on both sides of each gasket, because this prevents sticking of the gaskets to the flanges.

Caution: BE CAREFUL WHEN HANDLING THE WATER BOX COVER ON THE WATER BOX END TO SEE THAT THE DIVISION PLATE MATCHES THE RIB OF THE FLANGES.

- Tighten all nuts evenly.
- Close the drain and gage cock.
- Open the main water valve and fill the tubes with water. Operate the pump, if possible, to check for leak tight joints.

Re-tubing is about the only major repair that is done on the condenser. This takes a high degree of skill and may require the services of a manufacturer's qualified repairman.

You must make frequent checks of the chilled water temperature leaving the evaporator. If the temperature reading at full load begins to vary from the designed temperature, fouling of the tube surfaces is beginning, and cleaning is required when the leaving chilled water temperature cannot be maintained.

It is recommended that the tubes be cleaned at least once a year, though this may vary with local operating conditions. Cleaning schedules should be outlined in the standing operating procedures.

Servicing procedures for all shell and tube-type evaporator and condensers are the same, since all shell and tube containers are built and operated on similar principles.

Here again, re-tubing is about the only major repair that is needed on the evaporator. However, this work should be done by a qualified refrigeration technician or a manufacturer's repairman.

EXERCISE: Answer the following questions and check your responses against those listed at the end of the study unit.

1. Why is it necessary to operate the air handler immediately after lubrication?

   ____

   ____

2. Why is it necessary to vary lubrication intervals?

   ____

   ____

3. How do bearing lubricants affect rubber parts?

   ____

   ____

4. Why must blower bearings be checked periodically?

   ____

   ____

5. How do you determine whether or not a belt has proper tension?

   ____

   ____

6. Relate briefly the correct procedures to aline the motor and blower pulley.

   ____

   ____

   ____

   ____

7. Why must the pulley be alined properly?

   ____

   ____

8. What precaution should you observe while cleaning lint or foreign particles from the evaporator with compressed air?

   ____

9. During low temperature operating periods, why is it necessary for you to check the crankcase heater for proper operation?

   ____

   ____

10. How do you clean spray nozzles, jets, or rotary disks which cannot be cleaned satisfactorily by wire brush?

11. To what specifications do you adjust the float valve for proper water level in the cooler?

12. What type of paint do you apply to the surface of the water makeup tank?

13. Differentiate between a direct and an indirect expansion system.

14. What is a good indication that the surface of the cooler tubes are fouled?

15. What is happening if the temperature reading at full load of the evaporator or cooler begins to vary from the designed temperature?

SUMMARY REVIEW

In this study unit you have learned how to identify the components that make up the psychrometric chart and to extract the desired information. You also learned the different installation and maintenance procedures for selected air conditioning equipment and air-flow instruments that you may come into contact with in the refrigeration field.

Answers to Study Unit #5 Exercises

Work Unit 5-1.

1. By automatic control of the air across the evaporator coils.
2. The temperature of the vapor is always the same as that of the surrounding air.
3. The higher the temperature of the air, the more moisture the air can hold.
4. a. The amount of heat required to raise 1 pound of a substance 1° F.
   b. The temperature at which air ceases to be cooled by the process of evaporation.
   c. The difference between the dry-bulb and wet-bulb temperatures.
   d. The unit of measurement expressing the actual amount of moisture contained in 1 pound of dry air.
5. Saturated

6. a. 52 percent

   b. 67° F

   c. 36.7 Btu's

   d. 100

   e. .0143

7. A vertical line

8. It is a tool used to analyze the relationships of the properties of air.

9. At intersecting points of these lines and curves.

Work Unit 5-2.

1. It measures air velocity in linear feet.
2. 10 seconds
3. Allow the propeller to reach maximum speed.
4. Left; right; center
5. To measure the pressure of air in inches of water
6. Pressure of velocity
7. To allow access to the internal sections of the duct in hard to get to areas.
8. To measure the air velocity
9. The instrument will give a false reading if the filter is omitted.
10. A minimum of six readings

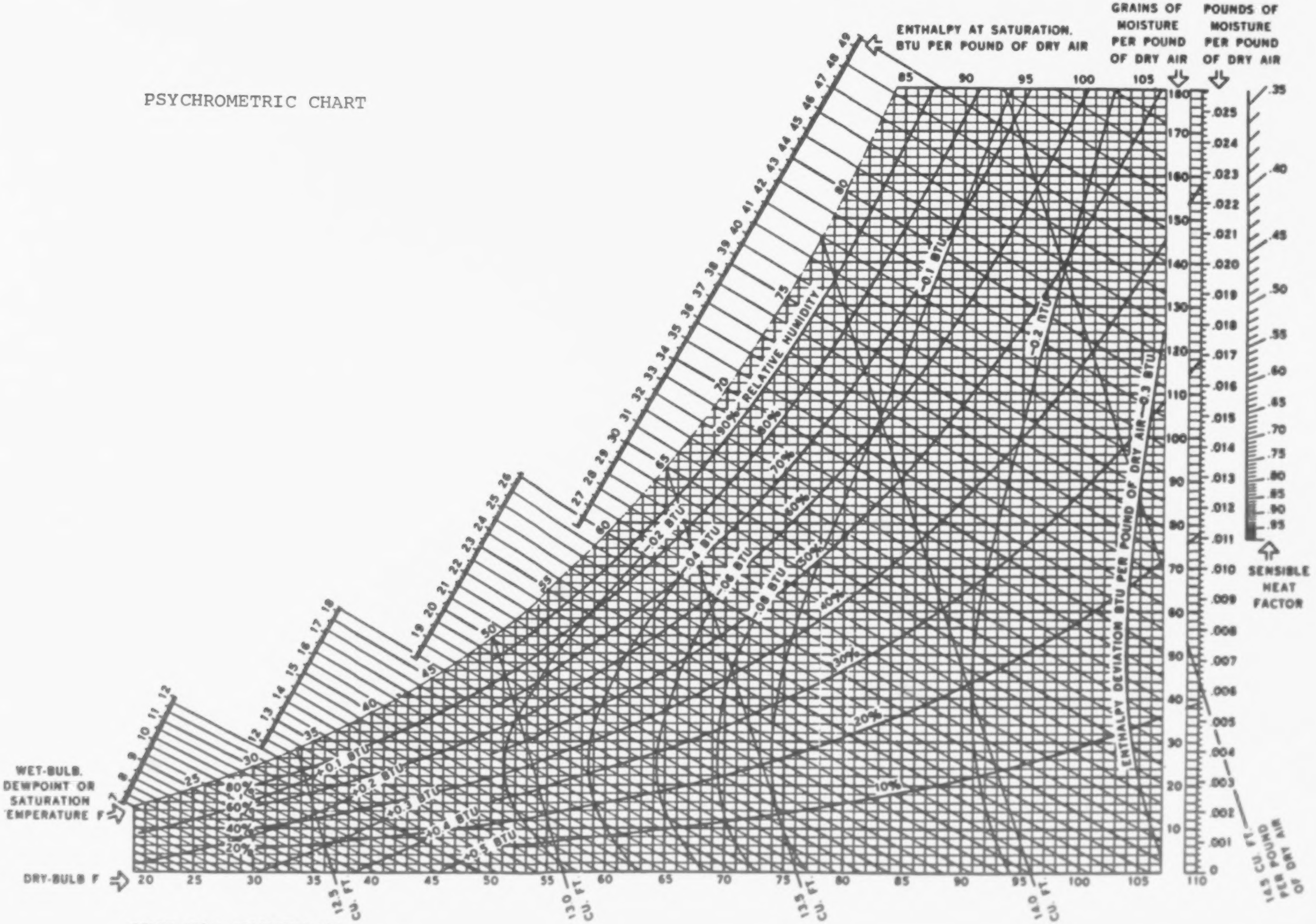
Work Unit 5-3.

1. This helps drain the condensation outside
2. At the top of the window
3. The size and style of the particular unit involved
4. 3/4 inch
5. To permit control of the unit while you are performing maintenance
6. On a cement platform, because it is more economical.
7. At least 1-1/2 inches in diameter to reduce drain stoppage
8. Air must be ducted to the outside
9. To prevent insects from crawling into the building or to keep air from blowing through the drain
10. To assist the oil return

Work Unit 5-4.

1. To evenly distribute the lubricants
2. To compensate
3. They may cause this material to deteriorate
4. To check the slippage or binding
5. Determine whether or not there is approximately 1/2 inch depression per foot between the centers of the pulley; if so, the proper tension is present.
6. Place the pulleys on their respective shafts. Secure one of the two pulleys to its shaft and then place a straightedge, a string, or a belt between the pulleys. Slide the unsecured pulley on the shaft until you are satisfied that the two pulleys are in line with one another. Secure the other pulley to the shaft
7. Because if the alinement is wrong, components that receive the power from the pulleys will wear unduly. Also, improper belt alinement will cause excessive wear and possible failure.
8. That severe air pressure does not damage the aluminum fins on the coils
9. Because such proper operation will protect the compressor from pumping liquid refrigerant.
10. Immerse these components in a 10 percent inhibited commercial hydrochloric solution.
11. Adjust the float valve to permit a constant water overflow for bleed-off into the standpipe.
12. Asphalt base paint
13. In the direct expansion system, the controlled variable comes into direct contact with a single refrigerant source. In the indirect system, the heat from the conditioned space is absorbed by a secondary refrigerant, such as brine or water.
14. The temperature reading at full load of the chilled water leaving the cooler begins to vary from the designed temperature.
15. Fouling of the tube surfaces is beginning, and cleaning is required when the leaving chilled water temperature cannot be maintained.

PSYCHROMETRIC CHART



BELOW 32° F. PROPERTIES AND ENTHALPY DEVIATION LINES ARE FOR ICE.

REFRIGERATION THEORY

REVIEW LESSON

INSTRUCTIONS: This review lesson is designed to aid you in preparing for your final exam. You should try to complete this lesson without the aid of reference materials, but if you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69) which will be mailed to your commanding officer with your final exam. You should study the reference material for the questions you missed before taking the final exam.

A. Multiple Choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

1. Identify the direction of heat flow in accordance with the thermal laws of refrigeration.

   a. From a body of high temperature to a body of lower temperature
   b. From a body of high pressure to a body of lower pressure
   c. From a body of high volume to a body of lower volume
   d. From a body of low temperature to a body of high temperature

2. During a change of state, the ________________ is constant during the change, provided the pressure remains constant.

   a. pressure c. volume
   b. temperature d. heat

3. While changing from a liquid state to a vapor state fluids ____________ heat.

   a. give up c. absorb
   b. transfer d. transmit

4. Heat energy and other forms of energy are

   a. destroyable. c. low temperatures.
   b. equal. d. interchangeable.

5. The evaporator and condenser require what essential characteristic in a refrigeration unit?

   a. Metallic parts that have a high heat conductivity
   b. Metallic parts that have fins
   c. Metallic parts that have insulation around them
   d. Metalllic parts that are able to expand

6. In which physical state are the molecules restricted to such a degree that the substance will maintain its shape?

   a. Solid c. Gas
   b. Liquid d. Vapor

7. In which physical state are the molecules much more free to move and as a result will not retain its shape?

   a. Gas c. Liquid
   b. Vapor d. Solid

8. Identify the physical state of a substance which, upon entering a container, will fill it uniformly with a small quantity.

   a. Water c. Liquid
   b. Gas d. Solid

9. The two measurements of heat are quantity and

a. volume.
b. pressure.
c. energy.
d. intensity.

10. Convert a room temperature of 32° C to its equivalent on the Fahrenheit scale.

a. 0° F
b. -25.6° F
c. 89.6° F
d. 194° F

11. Convert a room temperature of 75° F to its equivalent on the Celsius scale

a. -59.4° C
b. 23.9° C
c. 67° C
d. 75° C

12. Which heat measurement is defined as the amount of heat required to raise the temperatre of 1 pound of water 1 degree Fahrenheit at sea level?

a. Celsius
b. Fahrenheit
c. British thermal unit
d. Conduction

13. Calculate the amount of heat necessary to increase 4 quarts of water (8.4 lbs) from 10° C to 40° C.

a. 144.0 Btu's
b. 252.0 Btu's
c. 365.3 Btu's
d. 453.6 Btu's

14. What type of heat when added to a substance will cause the temperature to remain constant; however, a charge of state will have taken place?

a. Latent heat
b. Sensible heat
c. Celsius
d. Fahrenheit

15. Identify the heat that is added to a substance and the temperature rises but you know that a change of state has NOT taken place.

a. Latent heat
b. Sensible heat
c. Celsius
d. Fahrenheit

16. If you were to hold a 24 inch bar of steel in one hand and you placed one end of the bar in a flame, eventually you would feel the heat in your hand. What is this type of heat transfer called?

a. Latent heat of fusion
b. Conduction
c. Convection
d. Radiation

17. What type of heat transfer do you feel when you are laying on the beach in the sun?

a. Latent heat of fusion
b. Conduction
c. Convection
d. Radiation

18. The heat transfer that you feel being omitted from your home furance is called

a. latent heat of fusion.
b. conduction.
c. convection.
d. radiation.

19. Identify the heat transfer that is used most often in the refrigeration field.

a. Latent heat of fusion
b. Conduction
c. Convection
d. Radiation

20. The amount of force exerted on a substance per unit area is the definition for

a. volume.
b. pressure.
c. gas.
d. liquid.

21. The air that surrounds the earth has weight and exerts pressure. This is called

a. volume.
b. mercury.
c. absolute pressure.
d. atmospheric pressure.

22. If you had a pressure gage reading of 25 psig, what would be the absolute pressure?

a. 11.3 psia
b. 25.0 psia
c. 39.7 psia
d. 49.7 psia

23. The pressure gage most commonly used in the field by refrigeration technicians is the

a. manometer tube.
b. barometer tube.
c. Bourdon tube.
d. Toricelli tube.

24. Identify which pressure gage measures pressures above and below atmospheric pressures.

a. Compound pressure gage
b. Toricelli pressure gage
c. Suction pressure gage
d. Absolute pressure gage

25. The following formula $V_1P_1 = V_2P_2$ is the expression of which law effecting Pressure-Temperature-Volume relationships?

a. Boyles' law
b. Charles' law
c. General gas law
d. None of the above

26. The following formula $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ and $\frac{P_1}{P_2} = \frac{T_1}{T_2}$ is the expression of which law effecting Pressure-Temperature-Volume relationships?

a. Boyles' law
b. Charles' law
c. General gas law
d. None of the above

27. What is the basic purpose of the refrigeration cycle?

a. To make life more comfortable
b. To keep food from getting cold
c. To reduce bacteria growth
d. To remove unwanted heat from a space and discharge it into another space

28. What two pressures would you find in the refrigeration cycle?

a. Evaporator pressure and low pressure
b. Condenser pressure and high pressure
c. Evaporator pressure and condenser pressure
d. None of the above

29. If you could separate the refrigeration cycle into 2 parts, one high pressure and the other low pressure, which components would be the dividing line?

a. Evaporator and condenser
b. Receiver and compressor
c. Metering device and drier
d. Metering device and compressor

30. The unit which measures the amount of heat removal and thereby indicates the capacity of the refrigeration system is known as the

a. refrigeration ton.
b. British thermal unit.
c. absorption ton.
d. mechanical unit.

31. In a mechanical refrigeration system, what is the purpose of the refrigerant?

a. It lubricates the components of the system.
b. It absorbs heat from a place where it is not wanted and rejects it elsewhere.
c. It absorbs heat at a low temperature, and when compressed to a higher temperature, releases the absorbed heat to a cooling medium, thus affecting a heat transfer.
d. Both b and c

32. Refrigerants, in common use today, are fluids and are affected by ____________________, ____________________, and ____________________ in a manner similar to water.

a. temperature, pressure, and volume
b. heat, temperature, and pressure
c. temperature, heat, and volume
d. pressure, volume, and heat

33. If a leak occurs, what three chemical properties of a refrigerant must be considered?

a. Flammability, explosiveness, and stability
b. Explosiveness, toxicity, and density
c. Toxicity, flammability, and explosiveness
d. Density, volume, and latent heat content

34. In question 33, you identified three chemical properties of a refrigerant, what is the fourth?

a. Density
b. Stability
c. Flammability
d. Explosiveness

35. Critical temperature and pressure are two important physical properties of a refrigerant. Select three other physical properties that must be considered when selecting a refrigerant.

a. Boiling point, freezing point, and stability
b. Boiling point, miscibility, and stability
c. Miscibility, freezing point, and boiling point
d. Miscibility, freezing point, and explosiveness

36. Define primary refrigerant.

a. Fluids used in air-conditioning and refrigeration systems as heat carriers
b. Fluids that are a combination of two or more refrigerants
c. Fluids that lubricate the components of the system
d. Fluids used in the refrigeration system which are flammable, corrosive, and toxic

37. Of the following substances, which are classified as secondary refrigerants?

a. Fluorocarbon, halogen, and azeotropic
b. Brine, air, and azeotropic
c. Water, air, and brine
d. Air, water, and R-12

38. What are the two most prominently used refrigerants in the Marine Corps today?

a. R-11 and R-502
b. R-22 and R-114
c. R-12 and R-115
d. R-22 and R-12

39. In order for refrigerant R-12 to become a health hazard, what must occur?

a. Nothing because R-12 is nonpoisonous and nonexplosive
b. An accumulated leakage in a ventilated space or when it comes in contact with a low-temperature flame
c. An accumulated leakage in a nonventilated space or when it comes in contact with a high-temperature flame
d. An accumulated leakage in a nonventilated space or when it comes in contact with a low-temperature flame

40. R-12 is odorless in concentrations of less than 20% by volume in air; in higher concentrations, its odor resembles

a. mustard.
b. carbon dioxide.
c. carbon tetrachloride.
d. azeotropic.

41. At atmospheric pressure, identify the temperature at which R-12 will boil.

a. -21.7° F
b. -28.7° C
c. -40° F
d. 38° F
e. 70° to 75° F

42. Identify the refrigerant that is considered an ideal refrigerant because of its high stability and low operating pressures and temperatures.

a. R-11
b. R-12
c. R-22
d. R-502

43. Which refrigerant is used in units that can maintain temperatures as low as -20° to -40° F?

a. R-11
b. R-22
c. R-11
d. R-502

44. If R-22 is at atmospheric pressure, what is the temperature at which it will boil?

a. -21.7° F
b. -31.7° F
c. -38.5° F
d. -41° F

45. Identify the refrigerant that is often used as a flushing agent.

a. R-11
b. R-12
c. R-22
d. R-502

46. R-11 will remain a liquid at atmospheric pressure up to temperatures as high as

a. 65° F.
b. 70° F.
c. 75° F.
d. 80° F.

47. Identify, at atmospheric pressure, the boiling point of R-502.

a. -40° F
b. -50.1° F
c. -60.4° F
d. -65.8° F

48. Identify the only type of compressor in which R-502 can be used.

a. Centrifugal
b. Rotary
c. Reciprocating
d. Combination rotary and reciprocating

49. In a refrigeration system designed for R-12 to boil at 24°F and condense at 102°F, what would be the condensing pressure?

a. 120.86 psia
b. 120.86 psig
c. 135.54 psia
d. 135.54 psig

50. Identify the evaporator pressure for the conditions in question 49.

a. 38.574 psia
b. 38.574 psig
c. 23.878 psia
d. 23.878 psig

51. Identify the refrigeration effect for the conditions in question 49.

a. 48.32 Btu/lb
b. 66.39 Btu/lb
c. 108.81 Btu/lb
d. 151.03 Btu/lb

52. Identify the density of R-22 vapor at 32° F.

a. 1.326 lb/ft^3
b. 1.326 lb/ft
c. 13.26 lb/ft^3
d. 13.26 Btu/lb

53. Select the correct total heat content of R-22 vapor at -28° F.

a. 107.93 Btu/ft^3
b. 107.93 Btu/lb
c. 101.86 Btu/ft^3
d. 101.86 Btu/lb

54. Identify the absolute pressure of R-22 at a temperature of 46° F.

a. 42.656 psia
b. 44.651 psia
c. 57.352 psia
d. 59.347 psia

55. Assume that you have a refrigeration system designed to use R-12, rated at 36,000 Btu/hr. The evaporator temperature is 28° F and the condensing temperature is 100° F. Determine the quantity of refrigerant, in pounds per minute, required to circulate in the system to obtain the desired cooling level.

a. 734.69 lb/min
b. 73.46 lb/min
c. 12.245 lb/min
d. 1.225 lb/min

56. Identify what may occur if compressed gases are not identified and handled properly.

a. Nothing
b. The gas may escape
c. Personal injury
d. Personal injury and property damage

57. Decals on compressed gas cylinders show the amount of pressure to be retained in the cylinder for refilling. Identify two other statements found on the decal.

a. Name of the gas and the maximun pressure
b. Proper handling precautions and weight
c. Name of the gas and proper handling precautions
d. The pressure and weight of the gas

58. Identify the means which indicate the proper amount of refrigerant has been transferred to a service cylinder.

a. Weight
b. Pressure
c. Temperature
d. Heat

59. In refilling refrigerant cylinders, what is the maximun quantity of refrigerant that should be transferred to the cylinder?

a. 80%
b. 85%
c. 90%
d. 95%

60. In an open storage are, what protection is accorded refrigerant cylinders in the winter?

a. None
b. Protection from ice and snow
c. Protection from direct rays of the sun
d. Protection from other units

61. In an open storage area, what protection is accorded refrigerant cylinders in the summer?

a. Protection from other units
b. Protection from ice and snow
c. Protection from the direct rays of the sun
d. None

62. Identify an important aspect in the maintenance of the mechanical components of a refrigeration system.

a. An increase the refrigerant vapor flow
b. Reduce friction damage
c. Increase the components of a unit
d. Maintain the velocity of the vapor

63 What is the viscosity of a lubricating oil?

a. The temperature at which it will flow
b. The temperature at which the wax will be visible
c. The process that is used to remove hydrocarbons from the oil
d. Simply stated, its thickness

64. Identify the two principal methods used to lubricate the compressor in a refrigeration system.

a. 10W and 30W systems
b. Splash and hand pump systems
c. Splash and pressure systems
d. Pressure and vapor systems

65. What is the purpose of an oil separator in the refrigeration system?

a. To return the oil to the compressor as soon as possible
b. To separate the chemicals in the oil
c. To remove wax from the refrigeration oil
d. To maintain the velocity of the refrigeratant vapor

66. A mixed base is one of the three main categories of refrigerant oils. What are the other two?

a. Floc base and dielectric base
b. Paraffin base and wax base
c. Paraffin base and naphthene base
d. Naphthene base and wax base

67. What must you wear prior to entering a space that contains a system that uses a highly toxic refrigerant.

a. Gloves
b. Coat
c. Gas mask
d. Face shield

68. In the event that you must replace the evaporator in a system, what should you do first before opening the system?

a. Release the pressure in the system to 1 or 2 psi.
b. Nothing, just remove the evaporator.
c. Change the oil in the compressor.
d. Add more refrigerant so that the system is full.

69. If one of your men working for you was to get refrigerant R-12 on his arm, how would you treat it?

a. Give him CPR.
b Tell him to just lay down for a couple of hours.
c. Wash his arm in ice cold water.
d. Treat the affected area of the arm for frostbite.

70. Ice, evaporative, and dry ice are three refrigeration systems, identify the remaining two.

a. Absorption and compression systems
b. Ammonia and carbon dioxide systems
c. Compression and sealed systems
d. Mechanical and sealed systems

71. The most commonly used refrigeration system employed today is the

a. sealed system.
b. vapor compression system.
c. absorption system.
d. ice system.

72. There are four major components in the mechanical refrigeration system. Two of these are the evaporator and compressor. What are the remaining two components?

a. Condenser and receiver
b. Metering device and condenser
c. Receiver and metering device
d. Heat exchanger and condenser

73. Cylinders that are arranged in one straight line in a reciprocating compressor are known as

a. "V" arrangement.
b. "W" arrangement.
c. radial arrangement.
d. inline arrangement.

74. In the stationary blade rotary compressor, the blade is held against the roller by

a. centrifugal force.
b. an eccentric center.
c. a spring.
d. liquid pressure.

75. An advantage of a hermetic compressor over an open type compressor is that there is

a. a better oil seal.
b. no shaft spring.
c. a better arrangement of blades.
d. no shaft seal.

76. What is the most common symptom of a defective compressor?

a. Loose drive belt
b. Noise
c. Charred casing
d. Abnormal pressure

77. When troubleshooting for an electrical malfunction in an hermetic system, you should first check the

a. thermostat.
b. electrical power.
c. defrost control.
d. overload protector.

78. The number of amperes a 250 MFD capacitor at 120 volts, 60 cycle will draw is

a. 5 amperes.
b. 7 amperes.
c. 11 amperes.
d. 17 amperes.

79. The rate of heat transfer that takes place in the condenser depends on all of the following EXCEPT the

a. surface area.
b. type of cooling medium.
c. amount of cooling medium.
d. superheating temperature.

80. What does an air-cooled condenser use as its cooling medium?

a. Saturated air
b. Ambient air
c. Convection air
d. Humid air

81. To control the condensing pressure of a flooded condenser, a limiter valve is installed at the

a. inlet of the condenser.
b. outlet of the evaporator.
c. inlet of the compressor.
d. outlet of the condenser.

82. A water-cooled condenser has all of the following advantages except

a. they are compact.
b. they are easy to maintain.
c. they use a lower head pressure.
d. they increase condensing unit capacity.

83. Which type of condenser is used as a receiver?

a. Shell and coil
b. Double tube
c. Shell and tube
d. Evaporative

84. The refrigerant enters the evaporator from the

a. flow control.
b. compressor.
c. receiver.
d. condenser.

85. Identify the purpose of the accumulator in a flooded type evaporator.

a. It traps the vapor in liquid carryover.
b. It separates liquid from vapor carryover.
c. It engulfs the vapor for future use.
d. It entraps the liquid for future use.

86. Defrosting evaporators are used where temperatures

a. never go below 32° F.
b. never go above 32° F.
c. are below 32° F (compressor running) and above 32° F (compressor not running).
d. are above 32° F (compressor running) and below 32° F (compressor not running).

87. Why is a plate evaporator ideal for use in the fast freezing of foods?

a. It serves as a shelf.
b. It is compact.
c. It lowers the cost of freezing.
d. It is easily repairable.

88. The secondary refrigerant that is used in the tank-type coolers below 32° F temperature is

a. distilled water.
b. brine.
c. a mixture of various refrigerants.
d. any type of liquid.

89. The minimization of flash gas is a result obtained by the use of a(n)

a. filter-drier.
b. heat exchanger.
c. oil separator.
d. evaporator.

90. Identify the location of the oil separator in the refrigeration system.

a. Between the receiver and condenser
b. Between the evaporator and compressor
c. Between the evaporator and receiver
d. Between the compressor and condenser

91. Each of the following sources results in moisture in a refrigeration system EXCEPT

a. leakage from the heat exchanger.
b. contaminated oil.
c. low side leaks.
d. leakage during repairs.

92. Where are vibration absorbers usually located in a refrigeration systems?

a. In the suction and discharge lines
b. In the evaporator and condenser
c. In the sight glass and oil separator
d. In the compressor and discharge line

93. Where are mufflers usually located in refrigeration systems?

a. Suction line to the compressor
b. Liquid line to the metering device
c. Discharge line to the condenser
d. Liquid line to the heat exchanger

94. When a system has a low refrigerant charge the sight glass will indicate this by

a. visible bubbles.
b. an oil film.
c. being empty.
d. water spots.

95. Which one of the following pressure relief devices has an alloy center?

a. A spring-loaded safety valve
b. A pressure relief valve
c. A ruptured disk
d. A fusible plug

96. Which one of the following water regulating valves is probably the most popular?

a. Electric
b. Pressure-operated
c. Thermostatic
d. Electronic

97. Which of the following pressures activates a bellows and opens a suction pressure control valve?

a. 10 psi
b. 20 psi
c. 30 psi
d. 40 psi

98. In a two-temperature installation, a check valve is installed to

a. shut off one temperature.
b. regulate the temperature.
c. prevent vapor passage during off cycle.
d. prevent liquid flow during on cycle.

99. What is the basic component of a defrost timer?

a. A heating element
b. A fan element
c. A solenoid bypass valve
d. A self-staring clock

100. The size of the valve port in the direct-acting solinoid valve is limited by the

a. coil size.
b. valve seat.
c. armature.
d. pressure differential.

101. In automatic expansion valves, identify the element that is above the diaphragm to act as a cushion.

a. Moist air
b. Nitrogen gas
c. Atmospheric pressure
d. Refrigerant vapor

102. The automatic expansion valve is designed to maintain a fairly constant pressure in the evaporator. How much fluctuation in pressure is permissable?

a. 1/8 psi
b. 1/4 psi
c. 1/2 psi
d. 1 psi

103. The thermostatic expansion valve maintains a fully active evaporator by maintaining a constant degree of

a. dry air.
b. refrigerant.
c. pressure.
d. superheat.

104. Of the sizes below, which best represents the size of suction lines which have the thermal bulb positioned at 8 o'clock?

a. 1/2 inch
b. 3/4 inch
c. 2 inches
d. 3 inches

105. Which of the following statements is NOT an advantage of the gas-charged valve?

a. It prevents flooding of the evaporator in an off cycle.
b. It allows rapid pulldown.
c. It prevents overloading of the compressor motor.
d. It allows use on low-temperature application.

106. The capillary tube is located between what two components in a refrigeration system?

a. Compressor and condenser
b. Condenser and evaporator
c. Evaporator and receiver
d. Receiver and compressor

107. When does a capillary tube require a replacement which is exactly the same as the original?

a. When clogged or bent
b. When broken or plugged
c. After 1,000 hours of operation
d. Every 6 months

108. The purpose of the motor control in a system is to

a. prevent overloading of the compressor motor.
b. maintain a relatively constant temperature within the refrigerated space.
c. allow rapid pulldown.
d. prevent flooding of the evaporator in the off cycle.

109. Where is the thermostatic motor control power element attached in a unit.

a. On the condenser
b. On the evaporator
c. On the compressor
d. On the receiver

110. What activates the tube in a bourdon tube type control?

a. Temperature
b. Volume
c. Pressure
d. Humidity

111. What is the most useful item in the adjustment of controls?

a. Pressure gage
b. P/T chart
c. P/E chart
d. Pressure control setting chart

112. Which of the following malfunction conditions will give the same indication as a loss of charge of the power element?

a. Kinked tube	c. Worn points
b. Frosted tube	d. Pressure control setting out of adjustment

113. Motors are basically classified into what two groups?

a. AC and single-phase	c. Magnetic and nonmagnetic
b. Single and polyphase	d. Rotating and stationary

114. As a refrigeration technician, what are the three types of motors you would expect to find driving open type compressor?

a. Shaded pole, capacitor, and permanent split-capacitor
b. Repulsion-start induction, capacitor-start induction, and induction polyphase
c. Capacitor-run, capacitor-start induction, and universal
d. Capacitor-start induction, induction two-phase, and shaded pole

115. Identify the two types of motors used most often in hermetic compressors.

a. Split phase and shaded pole
b. Capacitor run and permanent split-capacitor
c. Capacitor-start induction and induction two-phase
d. Capacitor and shaded pole

116. As the temperature of air increases, the amount of moisture the air can hold

a. increases.
b. decreases due to pressure-temperature relationship.
c. decreases due to the dewpoint temperature in the air.
d. remains the same.

117. What is wet-bulb temperature?

a. The temperature at which air condenses
b. The temperature at which air is saturated
c. The difference in temperature between the dry-bulb and dew-point temperatures
d. The temperature at which air ceases to be cooled by the process of evaporation

118. The amount of heat required to raise one pound of a substance 1° F is called

a. total heat.	c. specific heat.
b. latent heat.	d. enthalpy.

119. The psychometric chart is used to

a. analyze the cleanliness of air.
b. analyze the relationship of the properties of air.
c. calculate the volume of air that passes through a cooling coil.
d. calculate the amount of air to be supplied to the conditioned space.

120. To begin a plotting procedure on the psychrometric chart, you must know the

a. dewpoint and wet-bulb temperatures.
b. grains of moisture and specific heat.
c. wet-bulb and dry-bulb temperatures.
d. dry-bulb and dewpoint temperatures.

Referring to the psychrometric chart provided in the course, determine the following:

121. If the wet-bulb temperature is 57° F and the dry-bulb temperature is 65° F, what is the relative humidity?

a. 57 percent	c. 65 percent
b. 61 percent	d. 70 percent

122. Using the wet and dry-bulb temperatures in the preceding question, what is the heat content?

a. 17.0 Btu
b. 19.5 Btu
c. 24.5 Btu
d. 30.0 Btu

123. Identify the purpose of the anemometer.

a. To measure the amount of air that passes through a cooling coil
b. To analyze the cleaning of air
c. To control the temperature and humidity of air
d. To measure air velocity in linear feet

124. In using the anemometer, in which sequence do you read the dials?

a. Left, right, and then center
b. Right, left and then center
c. Center, left, and then right
d. Center, right, and then left

125. A pitot tube is used in conjuction with a manometer if

a. the proper size jet is not available.
b. the manometer is that of an inclined type.
c. you need to take the velocity pressure reading in hard to get to places.
d. the velocity pressure in a duct is greater than the design limits of the manometer.

126. To measure the pressure of air in inches of water, you would use a(n)

a. pitot tube.
b. manometer.
c. velometer.
d. anemometer.

127. Identify the pressure within the duct system that the manometer measures?

a. Static pressure
b. Velocity pressure
c. Number of feet of air which will pass through a duct area in one minute
d. Pounds of air

128. For what purpose is the velometer used?

a. To measure the air pressure in the duct system
b. To measure the air velocity in the duct system
c. To measure the air density in the duct system
d. To measure the air temperature in the duct system

129. When a filter is supplied with the velometer, the filter

a. is most always used.
b. should be used only in dusty areas.
c. must be omitted in dust-free areas.
d. should be used only in kitchen areas.

130. Identify what will occur if the filter that is supplied with the velometer is omitted.

a. Nothing should happen
b. The instrument will give a false reading
c. The minimum number of readings must be reduced by three
d. The minimum number of readings must be doubled

131. Why should window air conditioners be installed with the outside portion of the unit titled down slightly?

a. To aid oil return to the compressor
b. To force the cool air from the unit to flow in an upward direction
c. To help drain the condensate to the outside
d. To reduce the friction applied to the fan motor bushings

132. A window air conditioner is to be installed so it is outside flush mounted. This means that the

a. outer face of the unit is flush with the outside wall.
b. inner face of the unit is flush with the outside wall.
c. outer face of the unit is flush with the inner wall.
d. inner face of the unit is flush with the inner wall.

133. Evaporative cooling is successful under what type of atmospheric condition?

a. Low dew-point temperature
b. High wet-bulb temperature
c. High relative humidity
d. Low relative humidity

134. What determines the location and type of supporting structure required for an evaporative cooler?

a. Ambient temperature and direction of air flow
b. Water pressure and type of filters
c. Model and size
d. Size and style

135. If an air-cooled condenser is part of a floor mounted air conditioning unit, the condenser must be

a. centered over a condensate sump.
b. connected to a valve.
c. ducted to the outside for cooling.
d. connected to a circulating pump.

136. Which of the following is NOT a type of evaporator used in central air-conditioning units?

a. A-type
b. Slant type
c. Flat type
d. Round type

137. When you lubricate air-conditioning unit bearings, you should

a. wipe grease fittings and surrounding surfaces clean before applying lubricants.
b. keep lubricants in open containers.
c. oil the bearings while the air handler is running.
d. not worry about getting lubricants or rubber parts.

138. A lack of proper bearing lubrication will cause

a. bearings to become dirty.
b. excessive wear and seizing of bearings.
c. proper distribution of the lubricant.
d. a prolonged period of operation.

139. Once a bearing has been adjusted, it must be checked periodically for

a. the proper size jets.
b. volumetric titration.
c. a slow rate of speed.
d. slippage and binding.

140. When the unit is off, a belt check will reveal whether or not the pulleys are out of alignment. How is this determined?

a. By excessive wear on the edge of the belts
b. By excessive wear on the edge of the shaft
c. By percent of lithium bromide on the belts
d. By the troughs being slotted

141. Why must the pulley be alined properly?

a. To prevent damage to the shaft
b. To prevent excessive bearing wear and possible failure
c. To prevent the slots from wearing out
d. To avoid getting lubricants on the rubber insulation

142. Heat pump maintenance is similar to maintenance performed on which, if any, of the following?

a. Electric heating systems
b. Fresh air systems
c. Refrigeration systems
d. None of the above

143. What is used to prevent freezeup of the outside coil on a heat pump?

a. Defrost thermostat
b. Reversing valve
c. Solenoid valve
d. Regulator valve

144. To evenly admit water to the top pad surface of an evaporative cooler, adjust the

a. weirs.
b. troughs.
c. float valve.
d. circulating pump.

145. Spray nozzles, jets, and rotary disks can be cleaned by immersing then in

a. phosphates.
b. muriatic acid.
c. sulphuric acid.
d. calcium hypochlorite.

146. Which choice presents a characteristic of an indirect expansion system?

a. Two or more compressors piped in series
b. Two or more evaporators operating in a single space
c. Controlled variable comes in contact with a single refrigerant source
d. Controlled variable comes in contact with a secondary refrigerant source

147. Identify what is happening if the temperature reading at full load of the evaporator or cooler begins to vary from the design temperature.

a. Fouling of the tubes surfaces are beginning
b. The freezing point of the brine mixture is becoming to high
c. The brine solution is cooled to a subzero temperature
d. Nothing, this is normal.

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Section 2. CHECK THE APPROPRIATE BOX AND FILL IN THE APPROPRIATE SPACES.

FOR REGULAR AND CLASS II RESERVE MARINES THIS FORM MUST BE SIGNED BY THE COMMANDING OFFICER OR HIS REPRESENTATIVE, i.e. TRAINING NCO.

1. EXTENSION - Please grant an extension (will not be granted if already on extension.)
2. NOTICE OF COURSE COMPLETION - Final Exam Sent On_______. (New exam will be sent if exam not received at MCI.)
3. REENROLLMENT - Student has course materials (See para. 4003 of Vol. I of MCI Catalog for information on reenrollment.)
4. OVERDUE FINAL EXAM - Last (Review) lesson sent on __________. Please send exam.
5. Please send new ANSWER SHEETS.
6. Please send missing course materials (Not included in course package.) Lessons____ Manual_____ Other______________
7. CHANGE - Rank________ Name______________ Social Security Number RUC____________
8. OTHER (explain)____________________

FOR MCI USE ONLY

1. D____
2. On SMF____ K____ L____
3. C____
4. L____
5. Q____
6. P____
7. E____
8. ________________

DATE COMPLETED______________

ORIGINATOR CODE______________

Note: This form will not be returned by MCI. If request is valid, transaction will show on next UAR or on MCI-R1_ form.

____
SIGNATURE-TITLE OR RANK
(MUST BE CO OR REPRESENTATIVE)

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STUDENT: Detach and retain this portion.

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 522A)

1. AUTHORITY: Title 5, USC, Sec. 301. Use of your Social Security Number is authorized by Executive Order 9397 of 22 Nov 43.

2. PRINCIPAL PURPOSE: The Student Course Content Assistance Request is used to transmit information concerning student participation in MCI courses.

3. ROUTINE USE: This information is used by MCI personnel to research student inquires. In some cases information contained therein is used to update correspondence course and individual student records maintained by the Marine Corps Institute.

4. MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION: Disclosure is voluntary. Failure to provide information may result in the provision of incomplete service to your inquiry. Failure to provide your Social Security Number will delay the processing of your assistance request.

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 12503 WASHINGTON D. C.

POSTAGE WILL BE PAID BY U.S. MARINE CORPS

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE
ARLINGTON, VA 22222-0001

DETACH BEFORE MAILING